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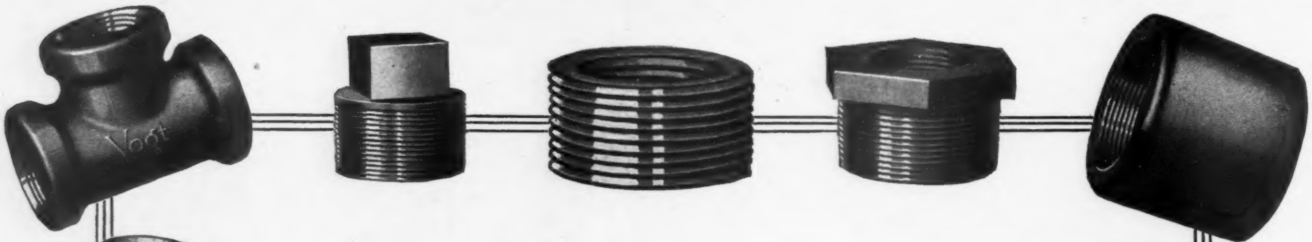

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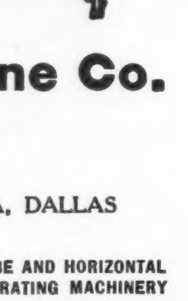

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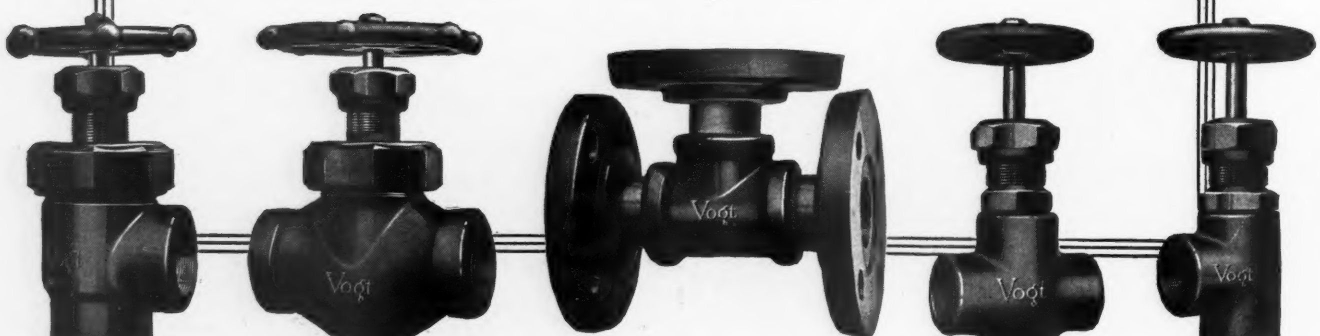

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MARCH, 1924

Efficiency of Present-Day Pneumatic Rock Drill Due to Superior Workmanship

Great Care Must be Taken and Much Time is Required to Turn Out a Rock Drill Capable of Meeting the Varied Demands Made Upon It

By ROBERT G. SKERRETT

TUNNELING through thirty-eight miles of primeval rock, opening great passages in the backbones of mountains that water may flow to thirsty millions or turn the monster turbines of hydro-electric stations are notable engineering undertakings being pushed to completion in some sections of California.

San Francisco's Hetch Hetchy water-supply project; the impressive hydro-electric developments of the San Joaquin Light & Power Company; and the wonderful work being carried forward on Big Creek by the Southern California Edison Company are all tasks which would be prohibitively costly and very long drawn out but for the performances of pneumatic rock drills.

The present article tells in a popular way something about the splendid service given in the shops where rock drills are made—a service that insures a superior product and turns out drills capable of driving steels into the hardest and sturdiest of Nature's barriers.

THE BEST of modern rock drills are built with a watchmaker's care and yet are as rugged as battering rams. Indeed, these tools, so essential to the rapid prosecution of construction jobs of divers kinds, would not be equal to the tasks set them if workmanship of the highest order had not made them what they are.

To understand what the inventor has done, what the mechanical engineer is doing, and what the shopman does in this department of industry, let us first outline the circumstances under which the rock drill performs. As a prelude to our story of service in the shop we shall describe briefly how the pneumatic drill simulates in some ways the hand tools which it supplants.

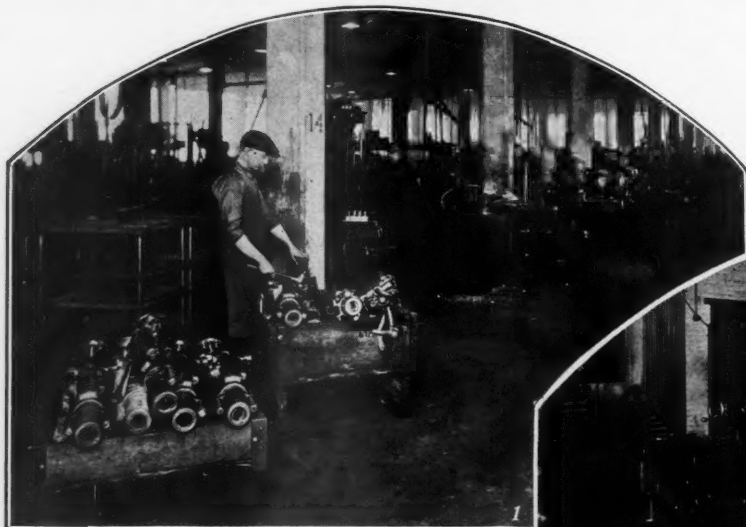
Before the days of the wide adoption of power-driven rock drills, holes for blasting were drilled with steels, held by hand, which were struck deliberate blows either by fairly heavy sledges, termed "double jacks," or by one-handed hammers of lighter weight commonly called "single jacks." After every blow or so, the drill steel was rotated manually to prevent the bit from jamming or wedging in the bottom of the hole; and every now and then the steel had to be lifted out and the cuttings removed. If this was not done, the accumulated material interfered with the action of the drill, and the bit was not able to bite into virgin rock at every hammer blow.

In driving most tunnels, as in most mining, water is encountered in penetrating the rock or ore body, and this leads to a condition which is likely to be hurtful to machinery or tools exposed to it unless care be taken to protect them from the corrosive action of moisture or water. The situation, however, is made worse by the presence of granulated or pulverized rock. This, when mixed with water, forms a slippery but abrasive sludge; and it is no uncommon thing in workings to see drill steels, drills, and their associate mounts and appurtenances either lying in this gritty mud or spattered with it. Besides, the drills are commonly subjected to very rough treatment. Even where water does not trace its way through the rock, still water is carried to the headings and distributed through the drills and the drill steels to the bottoms of the drill holes for the very purpose of washing out rock cuttings and, incidentally, to suppress the spread of dust harmful to the physical well-being of the operatives. Therefore, water and rock sludge are ever present as a menace to the drills.

Right here it might be well to describe broadly the essential features of a rock drill which render it capable of doing the work for which it is designed and enable it to utilize efficiently and effectually the compressed air which constitutes its operating force. Further, we might emphasize that the rock drill must be strong enough to stand up to its task when driving steels into the hardest and the toughest of rock and yet be light enough in construction to permit the drill runner to handle the tool readily when putting it into position for work or when shifting it from point to point.

In principle, the pneumatic rock drill makes use mechanically of the hammer blow of the old hand driller. By reason of this the present-day tool puts its full energy into every blow struck the drill steel, and the latter, therefore, does its utmost in cutting the opposing rock. The drill steel does not work up and down at each movement of the mechanical hammer: it is held loosely by a chuck in the fronthead of the drill. This chuck partly rotates the steel at every other stroke and keeps the bit in contact with the rock attacked. The air-driven hammer or piston is, accordingly, free to travel back and forth—that is, to reciprocate independently of the drill steel; and it has thus little friction and inertia to overcome in doing its designed work. In other words, the weight and the length of the drill steel have no hampering effect upon the rapid and the uniform action of the piston.

Perhaps we can show by contrast what the drifter in question, a "Leyner-Ingersoll" No. 248, represents as an advance in the art over the erstwhile hand hammer and drill steel. Using



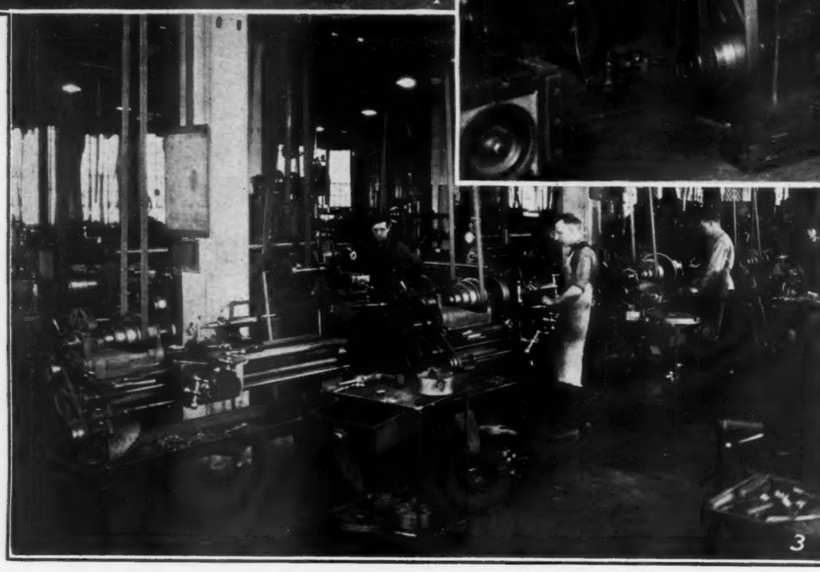


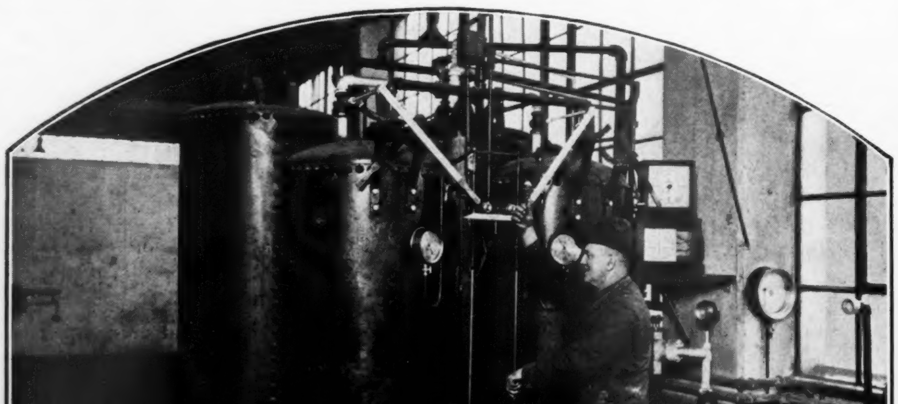
Fig. 1—New rock drill in process of manufacture in the special-production department.

Fig. 2—Another corner of the special-production department where the machinist is working on the rifle bar of a new type of rock drill.

Fig. 3—Part of the experimental department where highly skilled machinists make the first or model unit of each new type of rock drill.

a single jack weighing 3½ pounds, an experienced miner or driller could strike 16 blows a minute and maintain that pace for some while. The piston of the pneumatic drifter weighs 9 pounds, and it strikes 1,600 blows a minute, for example, when actuated by air at a pressure of 70 pounds. Each of these blows hits the drill steel with a force of nearly 25 foot-pounds—yielding a cumulative impact of substantially 40,000 foot-pounds in 60 seconds! With air at a higher pressure the work done is correspondingly increased. What we wish to make clear is that the mechanical drill does many times more in a given period than the hand worker; and the pneumatic tool can maintain this pace with undiminished energy hour in and hour out as long as motive air is fed to it. This difference explains in large part how it is possible with two drills of this sort, for instance, to drive 282 feet of a 12x11-foot tunnel in the course of a single month.

The amazing thing is that a 9-pound piston or hammer, traveling but 3 inches at each stroke, should be able to achieve such results; but the mathematician points out that it is the square of the velocity of each piston stroke that mainly determines the magnitude of the impact when the piston and the shank of the drill steel meet. It should be evident that the drifter must be so fashioned that the piston can withstand the arresting shock of these rapid blows and that the tool, as a whole, must be capable of absorbing the reactions without fracturing or flying to pieces. The piston has been aptly termed "the heart of the pneumatic hammer," and the greatest care has to be exercised in choosing the metal from which it is made, in machining it, and then in heat treating and hardening it so that it will be able to do its part in service.



Testing department equipped with special apparatus by which it is possible to determine all phases of the performances of a new rock drill. Among the data so obtained is the exact amount of compressed air required to operate a drill efficiently and economically.

It is not practicable in this article to enter further into the mechanical niceties of this particular type of drifter. We shall have to be content in saying that the piston alone requires 45 separate operations in its manufacture and that it is so assembled within the cylinder and so interconnected with a rifle bar at one end and a drill chuck at the other that its motion serves to partly rotate the drill steel at every second stroke. The arrangement

is such that the piston is virtually free on its outward or forward stroke to give all its energy to striking the drill steel—thus insuring maximum penetration of the rock.

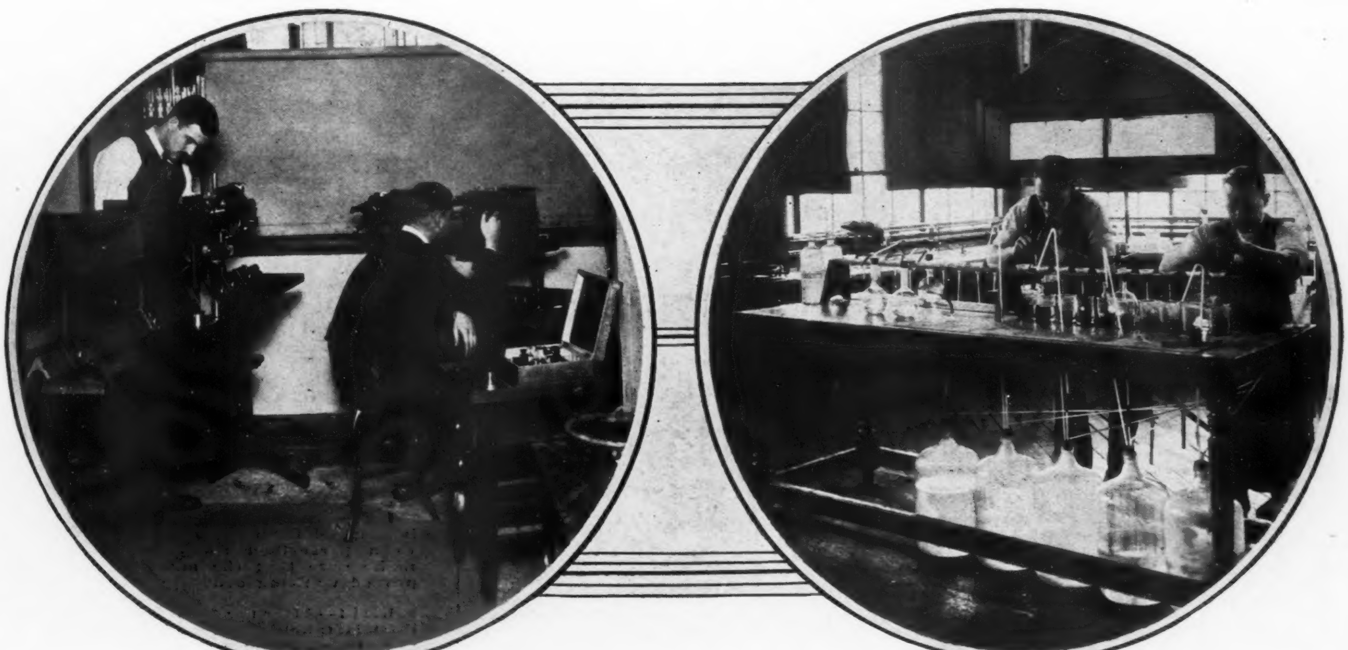
The layman may well wonder how it is feasible to produce a piece of machinery of comparatively light weight and high power and yet make it dependable and sturdy enough to do its work well day in and day out despite rather indifferent treatment in the field. Outwardly, the modern rock drill is a relatively simple-looking tool, but inwardly it is composed of a number of ingeniously interrelated parts which are fabricated from carefully selected materials. The manufacture of these parts puts the skill of the machinist to the utmost test, because permissible tolerances in a number of cases do not exceed .0015 of an inch. The external features of the rock drill, the mounting, etc., while not formed from steels of the same high grades, are, nevertheless, fashioned of metal having prescribed physical characteristics and, therefore, capable of standing up under the most rigorous service conditions.

These contrasting requirements could not be satisfied if the design of each structural part were not given particular attention or if the drill, in its entirety, were not built so as to produce a beautifully balanced machine. Perhaps we can make the engineering problem a little clearer if we follow the various stages by which a rock drill is turned out at the Phillipsburg plant of the Ingersoll-Rand Company. The reader will then be able to appreciate the really exquisite work which goes into the making of an air-driven tool intended to supplant the human hand and the somewhat primitive hammer.

Before dealing with the high points in the quantity production of some of the principal features of the "Leyner-Ingersoll" drifter, let us make a brief survey of the work that precedes this process of manufacture. It will help us to a fuller understanding of the steps that must be taken and of the thought, the care, and the expense required in turning out these drills. We shall assume that the designing engineers, with a thorough grasp of the state of the art and with an intimate knowledge of what rock drills are expected to do and are doing, decide that a new or improved type is practicable. When their plans are ready—and this may represent months of deliberation—the approved drawings are turned over to the experimental department and there given form by a force of highly skilled machinists. The drill, when finished, is then taken in hand by the testing department where it undergoes trials that are intended to reveal weaknesses or to verify the expectations of the designers.

For the sake of our story, we shall conclude that the experimental unit has done well enough to warrant the company in manufacturing a considerable number of them to be sent to various points in the field where they can better demonstrate their fitness and their superiority under service conditions. This lot of drills is made in what is known as the special-production department of the Phillipsburg plant, where are installed an array of machine tools and a corps of machinists familiar with the

This Riehle testing machine, in the laboratory, determines the tensile strength of materials to be used in the shops. The apparatus is capable of developing a pull of hundreds of thousands of pounds.



Fractured sections of the steel used or to be used are scrutinized by means of powerful microscopes so that weaknesses invisible to the unaided eye may be brought to light. The composition of the various steels employed is verified by chemical tests in the laboratory. The fitness of steel for certain purposes is dependent upon the proportion of carbon and other alloys combined with the basic iron.

handling of tasks of this exacting character. Naturally, this lot of drills costs a good deal more than would be the case if made by quantity-production methods. However, this is the price that must be paid in blazing the way for betterment and in keeping ahead of the procession in developing drills capable of more effectually penetrating rock.

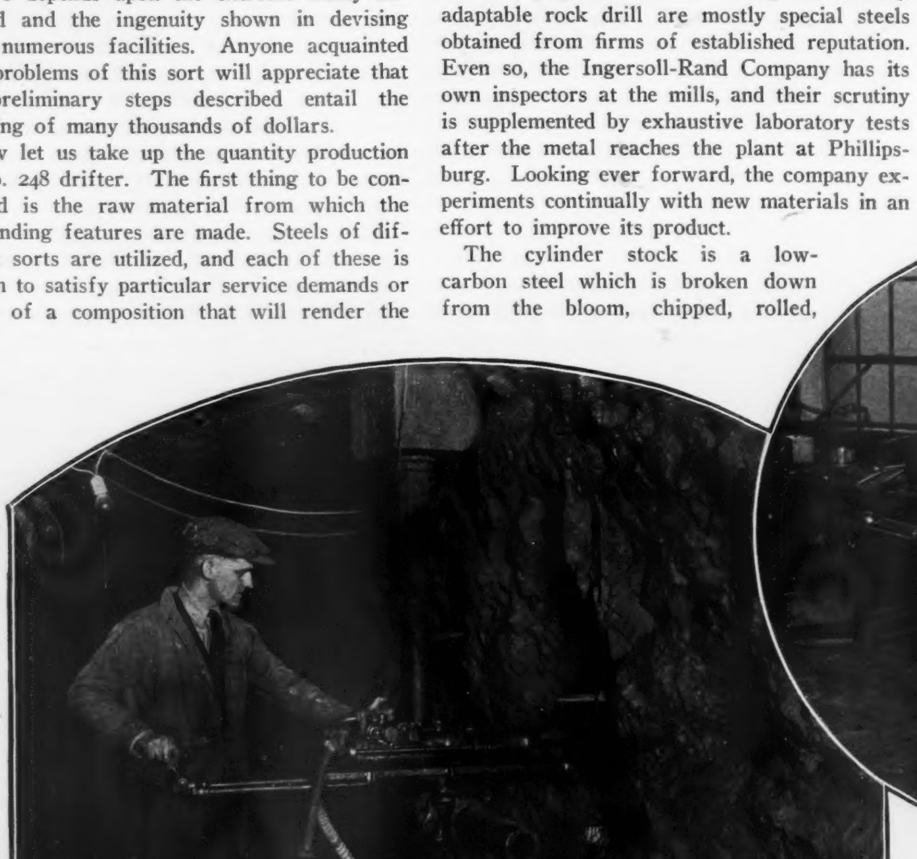
Plug gages of many different sizes are employed in the testing department of the machine shop for the inspection of the various bores of drill parts. A trifling matter of one-thousandth of an inch determines whether or not the work is acceptable.

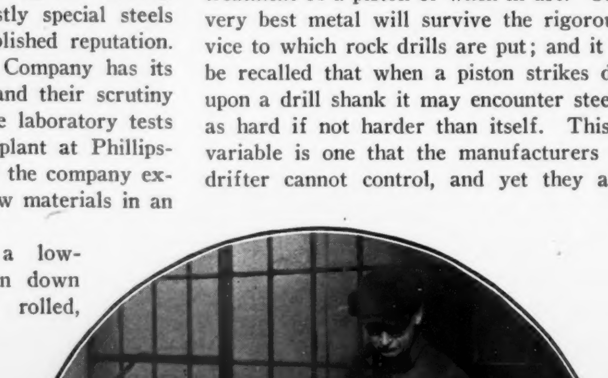
When the reports from the new demonstrating drills make it undeniably plain that these tools are satisfactory and a worth-while advance over those that have preceded them, then the next thing is the preparation of the jigs, dies, and other special fittings needful in equipping the shops for quantity production. This work is done in a toolroom by men used to particular jobs of this kind. Much of the success that follows depends upon the extreme nicety exercised and the ingenuity shown in devising these numerous facilities. Anyone acquainted with problems of this sort will appreciate that the preliminary steps described entail the spending of many thousands of dollars.

Now let us take up the quantity production of No. 248 drifter. The first thing to be considered is the raw material from which the outstanding features are made. Steels of different sorts are utilized, and each of these is chosen to satisfy particular service demands or to be of a composition that will render the steel suitable after metallurgical treatments that are necessary during certain stages in the fabrication of the drill parts. In short, the steels employed in manufacturing this notably adaptable rock drill are mostly special steels obtained from firms of established reputation. Even so, the Ingersoll-Rand Company has its own inspectors at the mills, and their scrutiny is supplemented by exhaustive laboratory tests after the metal reaches the plant at Phillipsburg. Looking ever forward, the company experiments continually with new materials in an effort to improve its product.

The cylinder stock is a low-carbon steel which is broken down from the bloom, chipped, rolled, rechipped, and then pickled to free it of scale. It is what is termed special forging steel—a superior metal that lends itself to the making of drop forgings and then to heat treatments which impart to it distinctive qualities at points or in areas where hardness and added strength are required locally. We shall tell more about this phase of the subject a little later on.

The pistons are machined from the highest grade of steel obtainable, and are fashioned from bar stock. Slabs taken from both ends of a bar are heat treated, broken crosswise, and then intimately examined under powerful microscopes for any defects that might pass unnoticed by the unaided eye. This is because small defects become big ones during the heat treatment of a piston or when in use. Only the very best metal will survive the rigorous service to which rock drills are put; and it should be recalled that when a piston strikes directly upon a drill shank it may encounter steel quite as hard if not harder than itself. This latter variable is one that the manufacturers of the drifter cannot control, and yet they are ex-





Left—Every complete drill, before it is shipped from the plant, is subjected to a prescribed rock-drilling test to make sure that the machine is in approved working order.

Right—After the rock-drilling test the drill is taken apart and examined minutely by an expert to detect the slightest signs of physical failure.

pected to turn out a tool that will be equal to a wide range of changing and severe demands. One piston out of every lot of a hundred or so is tested to destruction in an especially designed apparatus.

Assuming that the incoming steel for cylinders has been passed by the metallurgical department of the plant, let us see what happens after it is delivered to the forge shop where it is formed into the blanks from which the cylinders of the rock drills are machined. To the informed, the number of essential operations is a partway index of the time required and the cost of manufacture. From start to finish there are nearly 100 of these operations in the case of a rock-drill cylinder. To begin with, each billet or slug of steel weighs 150 pounds, and the first thing that is done to it is to form a tong hold on one end by means of a 1,000-ton hydraulic press. The second operation consists of chipping and surfacing the slug to remove any superficial seams—hair-like or otherwise—before any more work is put on it. Next, the slug is inspected, and if found satisfactory it is then ready to be heated in an oil-burning furnace preparatory to drop forging it.

During drop forging the slug is first blocked out approximately to the desired shape and then given its finished form under the blows of an 8,000-pound drop hammer. This procedure lessens the stresses upon the finishing dies. These dies are made of alloy steel, and each of them represents an outlay of about $1,200. The dies may be damaged irreparably after a few blows, and, at best, they last but a comparatively short while. With the work of the drop hammer completed, the still glowing forging is set in a powerful press where the "flash" or excess metal is cut off. Any fin remaining is afterwards removed by pneumatic grinders; and with this done the forging is again inspected.

All told, seven operations are required to produce an acceptable forging for a cylinder; but other things must yet be done before the forging is ready to go to the machine shop.

The metallurgist will tell you that the hardness and the strength of a piece of forged steel—other things being equal—will depend upon the work put in the steel during its hammering, upon the temperature of the metal when the forging leaves the hammer, and upon the conditions under which the steel cools. That is to say, if the temperature at the end of forging be high enough, and the piece be permitted to cool slowly in the open air, then the granular structure will be larger and the metal less strong than it would be if the last blows of the hammer were delivered at a lower temperature. The purpose, therefore, is to take steps which will insure as far as possible the retention of the added strength imparted to the steel by the blows of the hammer which give the metal a finer texture. In the rush of a busy day, the final temperatures of the forgings will vary from piece to piece; and to average up these differences, to get a product of satisfactory uniformity, the cylinder forgings are annealed to remove any conflicting internal stresses and to bring about readjustments within the metal that will make it just right for machining. This calls for care and skill.

To anneal them, the forgings are heated to a prescribed temperature in suitable furnaces; and success depends upon the nice regulation of this temperature and the length of the annealing period. The annealing operation takes something like 24 hours. With this work done, the forgings are examined for superficial defects, and if they pass this inspection they are moved to the sand-blasting department where jets of abrasive sand clean off any scale and give the forgings a dull, silvery finish. They are now ready to be transferred to the machine shop where they undergo substantially 70 distinct operations.

Interesting as it undoubtedly would be to many to follow the machine-shop procedure, space, unfortunately, does not permit this elaboration. During this stage of manufacture, each cylinder blank is milled, bored, drilled, tapped, ground, and prepared with infinite care to receive and to be combined with the associate parts which make it a thing of life or action when compressed air is breathed into it. As previously mentioned, the rough or original billet for a cylinder weighs 150 pounds. The finished cylinder, on the other hand, weighs but 46½ pounds—in other words 103½ pounds of steel are scrapped in the making of it.

From the time a lot of half a hundred cylinder forgings enter the machine shop until they are converted into cylinders ready for shipment is a matter of from five to six months. To the casual reader this may seem rather

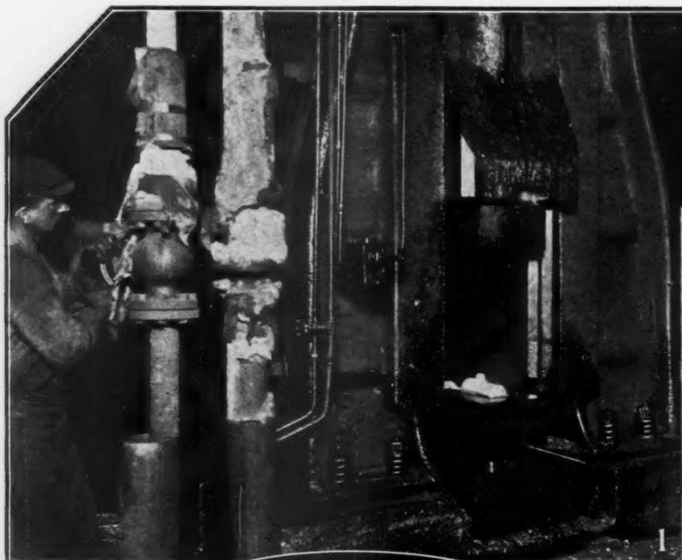
Fig. 1—A lot of blocked-down billets showing the ends which are to be gripped by the tongs when forging frontheads under the steam hammers. Fig. 2—Forming the tong end on a cylinder billet in a 1,000-ton hydraulic press. Fig. 3—Any surface imperfections are removed by pneumatic chippers before the partly formed slugs are drop forged. Otherwise hair-line imperfections might develop into serious cracks.

protracted, but it is really rapid work which would not be possible but for the skill of the machinists and the facilities at their disposal. Some of the apparatus are marvels of the machine-toolmaker's art; and no less wonderful are the jigs or fixtures devised to handle or to hold the developing cylinders at every stage so that each one of them will be exactly like its fellows. This is a prerequisite, because interchangeability is the special aim of the processes employed. Failing in this, it would be out of the question to provide replacement parts which would be sure to fit into "Leyner-Ingersoll" drifters in service anywhere. Further, the completed cylinder is so made that precision can be had if we mention that the cylinder bore must be within .0015 of an inch between the maximum and the minimum size of the prescribed diameter, and this dimension is verified by testing the bore with plug gages. Again, the piston which goes into this cylinder must be machined within .001 of an inch of the specified diameter; and the accuracy of this work is measured with micrometers by men skilled in the use of such instruments. Perhaps it will help to a readier grasp of these refinements if we say that cigarette paper is .002 of an inch thick and that newspaper is .0032 of an inch thick.

The cylinder front washer is an important part of the drifter because the closeness of the fit between it and the piston determines whether or not there will be sufficient air cushioning of the piston on its outward or downward stroke. Lacking this cushion, which arrests the advance of the piston at the desired point, the latter might strike the fronthead and split or shatter it. In the case of this washer, the permissible tolerance does not exceed .0015 of an inch. There is a valve in the cylinder which serves to relieve the back pressure in the machine so that the full blow of the piston will strike the drill steel. The bore of this valve must not be more than .001 of an inch in excess of the diameter called for, nor must the valve bolt which slides within this bore fall short of the diameter specified by more than .001 of an inch. Without going further into manufacturing niceties it should be evident why we said at the very beginning of this article that the best of modern rock drills are built with a watchmaker's care.

Most of us pay little heed to any part of an inch smaller than an eighth; but an eighth of an inch must be subdivided into 125 equal parts to cut it up into thousandths. It is only when the average person thinks of it in this way that he realizes the minuteness of a thousandth of an inch. Small as such a measurement is, still considerable light can be seen through a passage so narrow, and this fact should be kept in mind in judging by the eye the fit of a piston inside a cylinder. The optical effect of incoming light is misleading and tends to magnify the actual clearance. The permissible combined differences between a piston and the enveloping cylinder walls may give a total clearance of .003 of an inch. As long experience has proved, this variation is not enough to impair in the least the correct functioning of a drifter. The man in the field may be inclined to conclude that the fit is too loose, but he must remember that space is necessary for a suitable film of oil.

Some of the operations in the machine shop are sandwiched between other operations which



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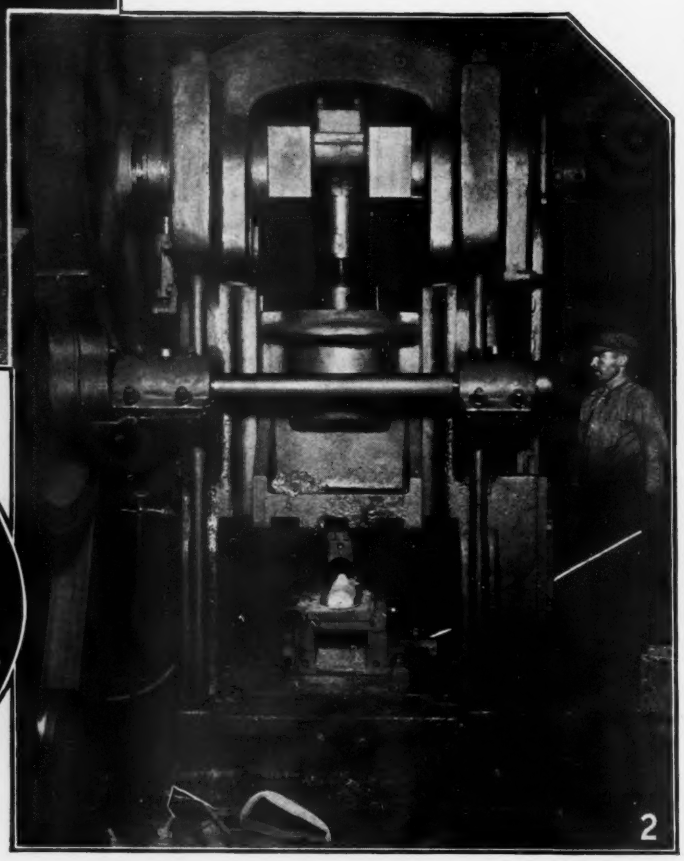

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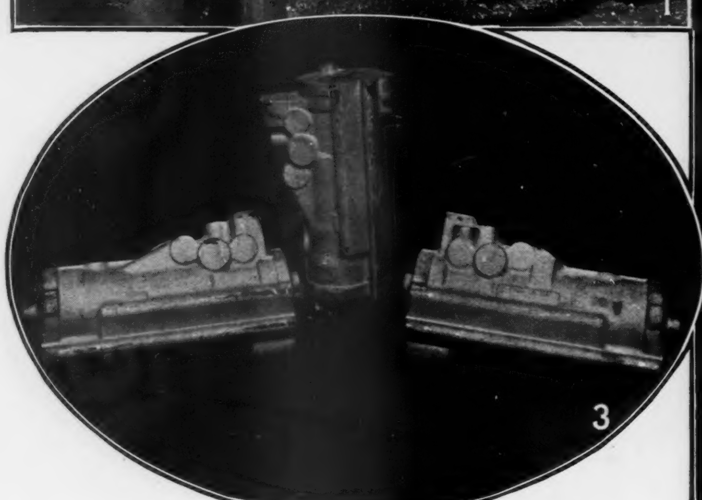


3

Fig. 1—Forging frontheads for drifters with an 8,000-pound steam hammer equipped with suitable massive dies of alloy steel. These dies are expensive affairs. Fig. 2—Powerful press cutting the "flash" or excess metal from a fronthead forging after it has been formed under the hammer. Fig. 3—Cylinder forgings for "Leyner-Ingersoll" drifters which have undergone sandblasting to remove surface scale.

considerable of the fine and precise work done on it is hidden from the eye, and yet this work has much to do with the way the drill performs.

Only by careful and continual inspection in the shop is it practicable to keep the producing tools in condition to turn out products of the required standard. Similarly, each part fabricated is watched by trained inspectors at every stage of its evolution, and any shortcomings are promptly corrected or, if this cannot be done, the defective part is scrapped forthwith. Some idea of what is demanded in the way of

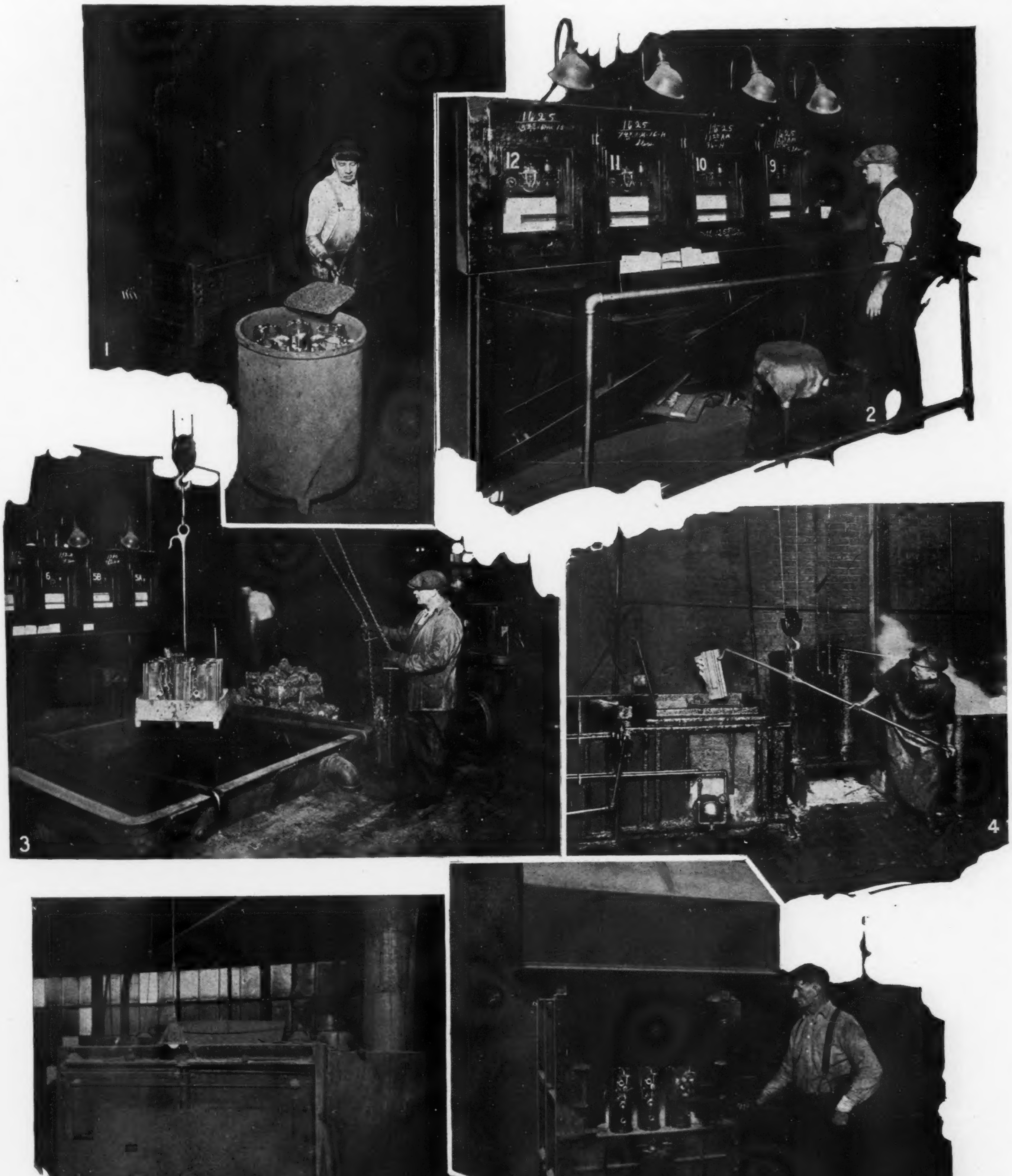


Fig. 1—Packing carbonizing material around a lot of cylinders preparatory to putting them in the carbonizing furnace. Fig. 2—A battery of electric recording pyrometers. Fig. 3—Quenching preheated rock-drill cylinders in an oil bath. Fig. 4—A cylinder which has been brought to the needful temperature in a saline bath about to be hardened by quenching in a cold bath. Fig. 5—A group of rock-drill frontheads after they have been sandblasted. Fig. 6—Muffle furnace for preheating purposes.

are carried out in the heat-treating department of the plant. We shall confine our consideration of this phase of the subject to what is done in the case of drill cylinders, and we shall deal with the topic broadly because the procedure is of a more or less confidential nature—success being the outcome of years of experimenting and the developing of ways and means commonly classed as "trade secrets." Even so, enough can be told to interest and to make plain the highly important character of heat treating. We shall see that it is possible to alter and to add at will to the physical characteristics of a steel body by subjecting it to certain ranges of temperature and by quenching or chilling it in baths of water, brine, or oil, according to the results desired. To be certain that the temperatures will be right and held so for definite periods, the heat-treating department is provided with an array of both indicating and recording electric pyrometers. These sensitive instruments are calibrated at short intervals to make sure that they are functioning correctly. This precaution enables the responsible operatives to have a visible check on all essential temperatures and to make it possible for them to keep the furnaces properly regulated. Without this control, uniformity of product could not be assured.

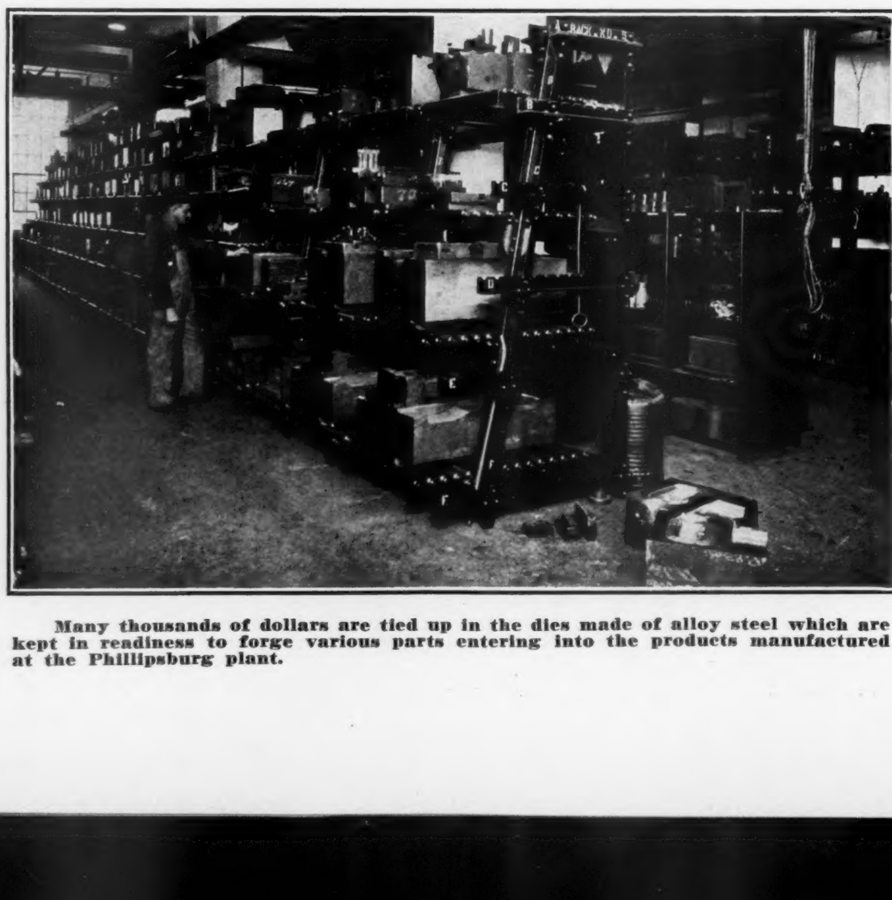
Electric jitneys are continually moving from point to point in the machine shop boxes laden with finished or partly finished drill parts. Thus the processes of manufacture go on without a halt during the working hours.

The first machine work in forming drill pistons from rough slugs of high-grade tool steel. At this stage each slug weighs 31 pounds while a finished piston weighs but 9 pounds. It takes fully four weeks to turn out a lot of 150 of these parts.

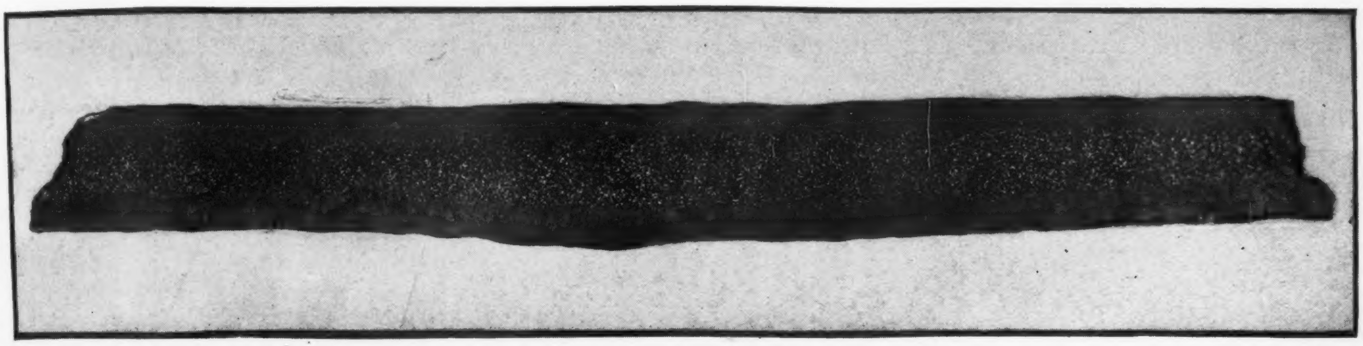
To avoid confusion, we shall now describe the work of the heat-treating department both in annealing the forgings before machining and in dealing with them afterwards. As we mentioned earlier, the drifter cylinder is fashioned of special low-carbon steel because high-carbon steel would be apt to warp or to crack during the hardening process. In short, the low-carbon steel gives a better finished product; and its adoption, combined with expert heat treating, permits the manufacturer to use this more tractable metal and yet to give it the strength and the hardness of high-carbon steel wherever the cylinder should have these characteristics.

For annealing, the cylinder forgings are placed in oil-heated furnaces and gradually brought up to a sufficiently high temperature. This takes something like seven hours. When heated through and through in this way the forgings are quenched in a water bath and then exposed to a temperature of approximately 1,000 degrees for a period of eleven hours. The effect of this treatment is to render the steel denser and more compact and to rid it of any "punkiness" which would be sure to cause trouble during machining. In short, the annealing gives the steel "ginger," that is, makes it practicable for the drills and other cutting tools to get through without clogging and without tearing the metal and producing rough and irregular work.

When the cylinders have been finished machined in certain parts, and some or all of these parts are to be hardened, the steel at those points must be carbonized to make it responsive to the hardening process. That is to say, those particular sections or areas of the metal must have their carbon content increased. This is done by packing carbonizing material about the surfaces to be affected—surrounding the rest of the cylinder with sand or some other non-carbonaceous material. Several cylinders are thus packed in an iron carbonizing pot, after which they are run into a furnace and brought up to the required temperature and held there—the entire period covering from 20 to 24 hours. The heat causes the steel to open up and to drink in the gas given off by the carbonizing compound, and this penetration is sufficient to produce, when the steel is hardened, a "case" or stratum of



Many thousands of dollars are tied up in the dies made of alloy steel which are kept in readiness to forge various parts entering into the products manufactured at the Phillipsburg plant.



This fractured section of heat-treated steel shows plainly the effects of hardening. The core of well-defined granular metal is sandwiched between the much finer-grained steel of the "case."

much denser, fine grained metal about 1/16 inch thick.

Now let us suppose that the cylinder, after carbonizing, has gone to the machine shop and there been given its final machining, and that it is returned a second time to the heat-treating department—this time to be hardened. The hardening procedure is one that may either make or mar the cylinder, and every step must be carried out with extreme exactness. In general terms, the process consists of the following essential stages: First, the cylinder is preheated in a muffle furnace; second, it is placed in a saline solution and retained there until it is heated throughout to a temperature of more than 1,000 degrees; and then the cylinder is quenched in cool brine. The quenching acts upon the steel like the intense grip of an invisible hand, compressing the metal until the case, when fractured, has the appearance and texture of "90-carbon" steel. One of our illustrations shows the effect of carbonizing and hardening. Thus a layer of hard metal—capable of withstanding severe wear although more brittle because of its treatment—is made integral with a core of supporting elastic metal peculiarly fitted to absorb vibrations or blows which might otherwise be harmful if not destructive to the case. But don't let us anticipate.

After the cylinder has remained in the chilling brine until cold it is shifted to a tank filled with boiling water in which it is left for a while until that moderate heat relieves the stresses set up in the steel during the preceding quenching and hardening bath. Finally, the cylinder goes into an oil bath which is held at a temperature of several hundred degrees; and the hot oil gradually brings about a further readjustment of the mass and disposes of the last of the undesirable stresses — it is really a sort of mild annealing. This oil bath also prevents the formation of surface checks or hair-like cracks which might develop during the concluding grinding operations. This grinding is done in the machine shop by means of disks of artificial abrasives hard enough to deal with the hardened steel. Following the so-called oil tempering, the cylinder is inspected and, if found satisfactory, is subjected to a second sand blasting.

It must be understood that the machine shop fabricates not only complete drills but thousands of spare parts which are held in stock at Phillipsburg or are distributed broadcast to the company's service stations the world over where they will be in easy reach of the customers in the field. Before a complete drill is shipped from the manufacturing plant it has to undergo a severe acceptance test. To standardize this test, a block of granite of uniform hardness is attacked by the drill. The drill makes three 1-minute runs—being fitted each time with a new sharp bit, and the aggregate result of that trial must come up to the specified penetration. Following this performance, the drill is taken apart and minutely examined by an expert to discover whether or not the

Left—A number of holes difficult to drill are required in each cylinder, but these holes do not appear when the cylinder is finished. Right—The final work on a cylinder consists in grinding the bore to exact dimensions by means of wheels of artificial abrasive.

machine shows any signs of failure or defects. Everything must be perfect to win the inspector's O. K.

What we have told about the manufacture of the drifter is also true of the quantity production of other rock drills at the Phillipsburg plant, and, similarly, the care exercised in making the parts described applies with equal force in turning out every part of any of these drills. Our story is somewhat longer than we intended, but even so we have had to leave out many interesting things which would have further emphasized the quality and the character of that splendid service in the shops that gives the rock drill its capacity to measure up to every demand made upon it.

"Leyner-Ingersoll" No. 248 drifters at work under ground.

GARDCO

THE name "Gardco" has been given to a new anti-corrosive solution intended to check the corrosion of iron, steel, and zinc. It is claimed that the solution, in addition to being rust preventing, resists the action of acid fumes, alkalis, and brines. Furthermore, it will not blister under heat and is unaffected by moisture. It has the appearance of an enamel or paint; has the consistency of varnish; and becomes tough and hard after it has been applied. The surface is said to harden chemically and not by a drying process; and various colors are available. Black hardens with a high gloss and other colors with a medium gloss. The solution may be applied by spraying, by dipping, or with a brush.

Part of the exhibit of the last 25 years of rock-drill development at the Phillipsburg plant. This is an example of the restlessness of the art and the continual effort of the company to achieve betterment and to keep always at the forefront.

EMPIRE MINING AND METALLURGICAL CONGRESS

HIS Royal Highness the Prince of Wales has consented to become Honorary President of the forthcoming Empire Mining and Metallurgical Congress which is to convene during the first week in June at the British Empire Exhibition in London. The following institutions are to coöperate: The Institute of Mining and Metallurgy; The Institute of Mining Engineers; The Institution of Petroleum Technologists; The Iron and Steel Institute; and The Institute of Metals will represent the scientific and technical interests of the mineral and metal industries, while The Mining Association of Great Britain and The National Federation of Iron and Steel Manufacturers will represent the colliery proprietors and the iron and steel manufacturers, respectively, of the British Isles.

This is the first Empire Mining and Metallurgical Congress to meet, and it is expected that succeeding sessions will be held under the auspices of an Empire Council of Mining and Metallurgical Engineering Institutions which, it is hoped, will be instituted as a result of the inaugural congress.

Viscount Long of Wraxall has accepted the invitation of the Institution of Mining and Metallurgy to deliver the "Sir Julius Wernher Memorial Lecture" at the opening session of the congress, and he has selected as his subject *Mineral resources and their relation to the prosperity and development of the Empire*. The "Hay Lecture" of the Institute of Metals, to be delivered by Dr. F. W. Aston, F.R.S., will also form part of the program. Dr. Aston's subject will be *Atoms and isotopes*.

PIPE BENDING HINTS

IN BENDING large pipe, fill with dry sand and plug the ends, but be sure that the sand is dry. Heat to a red heat in localities to be bent, and then bend. Where bends are slight, it is often unnecessary to use sand or resin. The object of sand or resin is simply to keep the sides of the pipe from collapsing, or to prevent the reduction of the flow area. If wet sand is employed, and if the ends are plugged, the pipe may burst when heated by reason of the steam pressure generated.

Resin is also a good medium for the purpose, but there is a right way and possibly several wrong ways to use it. An example of a wrong way was recently brought to our attention where a mechanic filled a pipe with resin, plugged the ends, and heated the pipe at the point where he wanted to bend it. He watched for a red heat just as he would have done had he filled the pipe with sand. The result was a violent explosion.

The way to utilize resin is to pour it into the pipe and to allow it to cool and to harden. As soon as the resin is hard, bend the pipe cold. Do not heat it. Then, after the pipe is bent, heat the pipe all over sufficiently to melt and to remove the resin.

In order to speed up the mail service, the Post Office Department of Melbourne, Australia, is having a pneumatic tube installed that is to be several city blocks long.

Cutting Concrete Caissons in an Exacting Foundation Job

BY GEORGE F. PAUL

LAYING the foundation for a modern skyscraper, with its tons upon tons of steel and stone, may sometimes prove to be a troublesome undertaking. This is especially true in the case of the unusually tall and spacious building that is being erected for the *Chicago Tribune*, on Michigan Boulevard. Most of the site on which the structure is to rise to a height of nearly 500 feet is at present free from obstructions, and presents no difficulties to the contractors; but the foundation on which the press extension building rests has offered something of a problem. This structure is a low and inconspicuous one architecturally; but it houses the great Goss presses which are so long that they extend into the lower part of the main 7-story plant.

When the foundation and shoring contractors consulted the printing-press experts and announced that it would be absolutely necessary to provide a much stronger foundation under the press extension building in order to furnish proper support for the immense skyscraper, a word of warning immediately came from the pressmen. They said, in substance: "Keep in mind all the time that these presses will not stand for any shifting of the foundation. The minute you disturb the floor level, then real trouble starts. Throw the presses a little out of alignment and you will tie them up as tightly as if you had called a general strike of the workers."

Doubling or quadrupling the foundation strength of an empty building may prove a comparatively simple matter, but to do this same work under a building containing machinery as ponderous and as sensitive as modern newspaper presses are calls for careful planning and coöperation. Changing the floor level just a fraction of an inch would cause the long, flowing ribbon of white paper to clog or to tear, and the presses would have to be shut down until all parts were again in alignment.

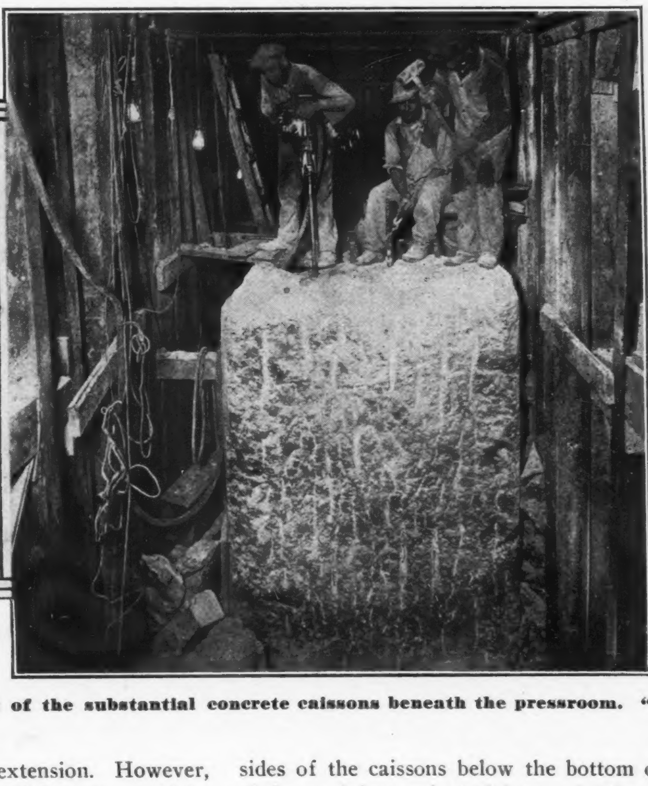
"The biggest difficulty we have been called on to face," said Mr. Gooder of the L. P. Friestedt Company, shoring contractors, "has come from the fact that there were really three kinds of foundations for the long pressroom. To the east, under the main plant, the press foundations are soil-bearing; at the junction of the main plant and the extension there are piles; and beneath the extension there are caissons on rock. According to our first plans we did not intend to disturb these caissons or the press framing in the extension. However, as we worked on, we found that it would be necessary to cut 15-foot sections out of six of these highly substantial caissons in order to give us room enough to place the reinforced-concrete distributing girders needed for the new column supports. We also found that we would have to shore the front row of columns for the 7-story plant. You see, the caissons under these columns will be called upon to support both the front of the present building and the rear of the new skyscraper.

"The work of cutting the 15-foot sections out of the six caissons was done by the R. C. Wieboldt Company, foundation contractors. Their men went to work with Ingersoll-Rand air hammers, and the way the sturdy caissons seemed to melt away when they were subjected to this concentrated attack was little short of amazing. The workmen drilled a series of holes, and then used the plug-and-feather method to clip off chunk after chunk of concrete. To have tried to do a job like this without resorting to compressed air would have been slow work. As it was, the men made fine progress, and they soon cleared the way for other operations in preparation for the bigger task that was to follow.

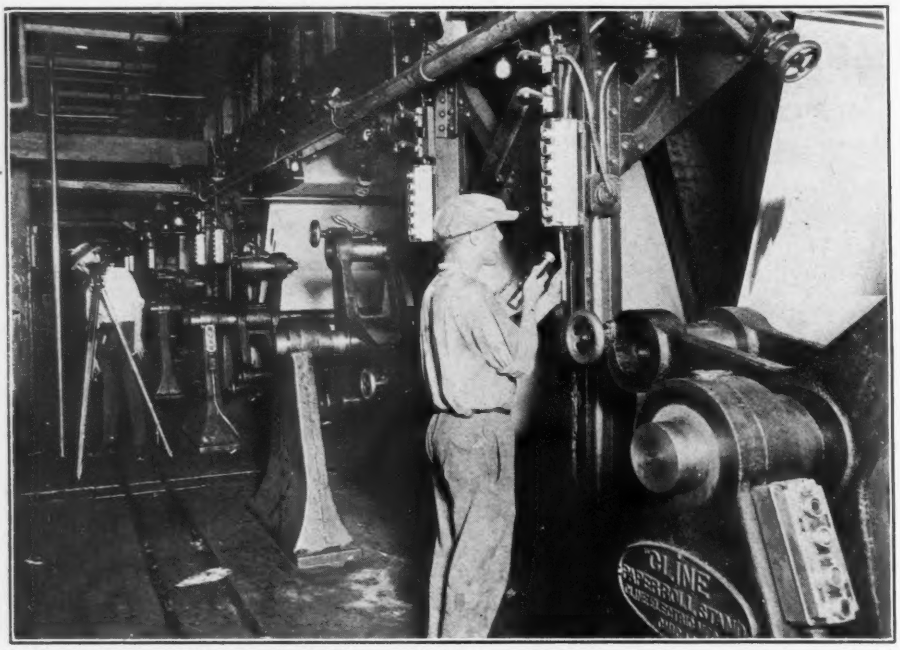
"It was necessary to make a trench 10 feet wide and extending down 35 feet from grade to bottom. This was needed to carry out the plan of using the caissons already in place in conjunction with the new ones through the medium of a reinforced-concrete distributing girder 100 feet long.

"To prepare for this, workmen cut into the sides of the caissons below the bottom of the girder and inserted steel beams in the niche. They cut in again above what would be the top of the girder. At the beam ends they placed wooden struts that were driven into position after the two sets of beams had been jacked apart in order to take up whatever deflection there might be. We used vertical steel walers to hold the sides of the trench in place. These walers carried the earth pressure to horizontal struts above and below the girder. The main object was to clear the girder of shoring of any kind so that all reinforcing rods and stirrups could be readily and correctly placed.

"The men taking alignment readings found that there was a tendency to shift south. Accordingly, we put in spur braces, using 16x16-inch timbers on 16-foot centers built up with eight 25-ton jacks. A stress of about 200 tons



Different phases of the exacting work of cutting 15-foot sections out of the substantial concrete caissons beneath the pressroom. "Jackhamers" were of the greatest help in doing this job.



Civil engineer, with transit, taking a sight to determine whether or not there has been any settlement of the pressroom floor.

per bearing point could thus be developed. We had to take readings continually to one one-thousandth of an inch. By these methods it was possible to keep the presses in service and also to insure a substantial foundation."

NEW INTERNAL-COMBUSTION MOTOR CARS

THE FIRST of three internal-combustion, motor-driven cars, for use on the Kampen-Zwolle line in Holland, has recently been delivered to the Nederlandsche Spoorwegen. The motors were constructed by the National Automobile Company, Berlin, and the car and other equipment were made by the Lurke-Hoffman works at Cologne. The car came from Cologne under its own power.

The car is supported by two 2-axle trucks, one axle of each of which is drawn by a 75-H.P., 6-cylinder gasoline motor placed at either end of the car. Transmission, reverse, and throttle are operated by compressed air. Controls are situated on both end platforms, and the motors may be regulated individually or jointly. The control mechanism includes a "dead-man's handle" that provides automatic stop. The car is designed for one-man operation, has Westinghouse brakes, Bosch-dynamo lighting, and is heated by the radiator water. The body is entirely of steel. Fuel consumption amounts to 1.26 quarts of gasoline per 1.24 miles, costing about twelve cents in United States currency. The maximum speed is 46.57 miles per hour. The car contains 25 second-class and 40 third-class seats, and has standing room for 20 persons.

Mr. W. L. Garrison, refrigerating engineer for the Ingersoll-Rand Company, has been elected President of the New York Section of the American Society of Refrigerating Engineers for the year 1924. Mr. Garrison is a graduate of Dartmouth College and Columbia University. During the World War he served as a first lieutenant in the Ordnance Department, American Expeditionary Forces.

A NEVER-STOP RAILWAY

THE British Empire Exhibition, which opens in April at Wembley, a suburb of London, is to be an affair of magnitude. Within the exhibition enclosure there are to be fifteen miles of roads, so, obviously, the show cannot be done on foot. Among several means of conveyance there is to be a non-stop railway with the unique and ingenious feature of running very slowly at the stations so that passengers can easily and safely step on or off. Between stations, however, a speed of 24 miles an hour will be attained.

The cars, which travel separately, are driven by a continuously rotating shaft lying below the level of the track. This shaft has a screw thread upon it whose pitch varies according to the speed required at different points en route. A roller arm, projecting down from every car, comes in contact with the thread and thus propels the vehicle. Each car is about 20 feet long, has room for 24 passengers sitting and 12 standing; and it is said that the system can carry 20,000 persons an hour each way.

MORE THAN THREE MILES A MINUTE

AN airplane racetrack, of 100 miles circuit around outer London, was planned more than a decade ago, and the eighth annual race over the course occurred recently. The speed attained showed an increase for each succeeding event.

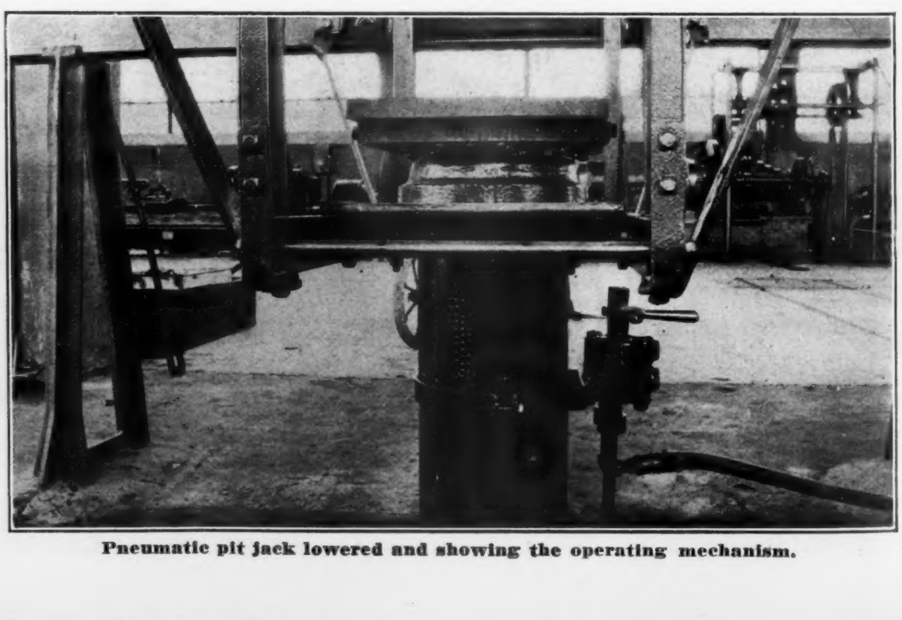
In 1912 the speed was 58.5 miles an hour, and in 1914 it was 72.15 miles. Then, after the war, from 1919 to 1923 inclusive, the speeds, in chronological order, have been: 129.38, 153.45, 163.34, 179.5, and 192.4 miles per hour. The last record was made by a 20-foot-span Gloster biplane with a 450-H.P. engine. It went twice around the course, 200 miles, in 1 hour 2 minutes and 23 seconds, at an average speed of 192.4 miles per hour, or 3.2 miles a minute. A mile a minute has been the ideal and still is the practical limit for a railroad train.

INGENIOUS PNEUMATIC JACK

IN THE repair shops of the Northern Texas Traction Company at Fort Worth, Tex., an interesting pneumatic pit jack is used. The pits being of the open type, the jack is so constructed that it will roll on the inside of the rails which carry the car to be repaired over the pit.

The bottom half of the motor with its armature is lowered by means of the jack, and after the armature has been rolled out from under the car it is removed by a swinging jib crane. It is claimed that free access to the poles and the field pieces is made possible by this method.

This novel type of jack is constructed of 3-inch channel iron with 3/16-inch corner gusset plates; and its wheels are ball bearings whose balls are so badly pitted that no other use could be found for them. The cylinder has a side adjustment of twelve inches. As a safety provision the plunger rod has a series of holes one inch apart into which a pin may be inserted at the proper place. The jack has a minimum height of three feet two inches and a maximum lift of five feet seven inches; and when in service it is hooked up to the regular compressed air line in the shop.



Pneumatic pit jack lowered and showing the operating mechanism.

Progress on the Big Creek Hydro-Electric Project

The Southern California Edison Company Builds Dams, Drives Tunnels, Constructs Roadways, and Rears Large Power Stations in Carrying Out its Vast Program of Hydro-Electric Developments

PART III

BY D. H. REDINGER*

IN THE present instalment of this engineering survey of the Big Creek undertaking attention is focused upon the work done and in course of prosecution on that section of the project officially known as Development No. 8. The tasks have been of diversified natures and in many instances of a character and magnitude calling for the utmost skill and resourcefulness on the part of everyone concerned.

The waters of Big Creek are again diverted from their channel at a point approximately 800 feet below Power House No. 2. The tunnel for this purpose and the associate power house are known as Development No. 8. This power house is the third and last of the hydro-electric stations situated on Big Creek—one of the principal tributaries of the San Joaquin River. The other power houses below this point are located on the San Joaquin River, itself.

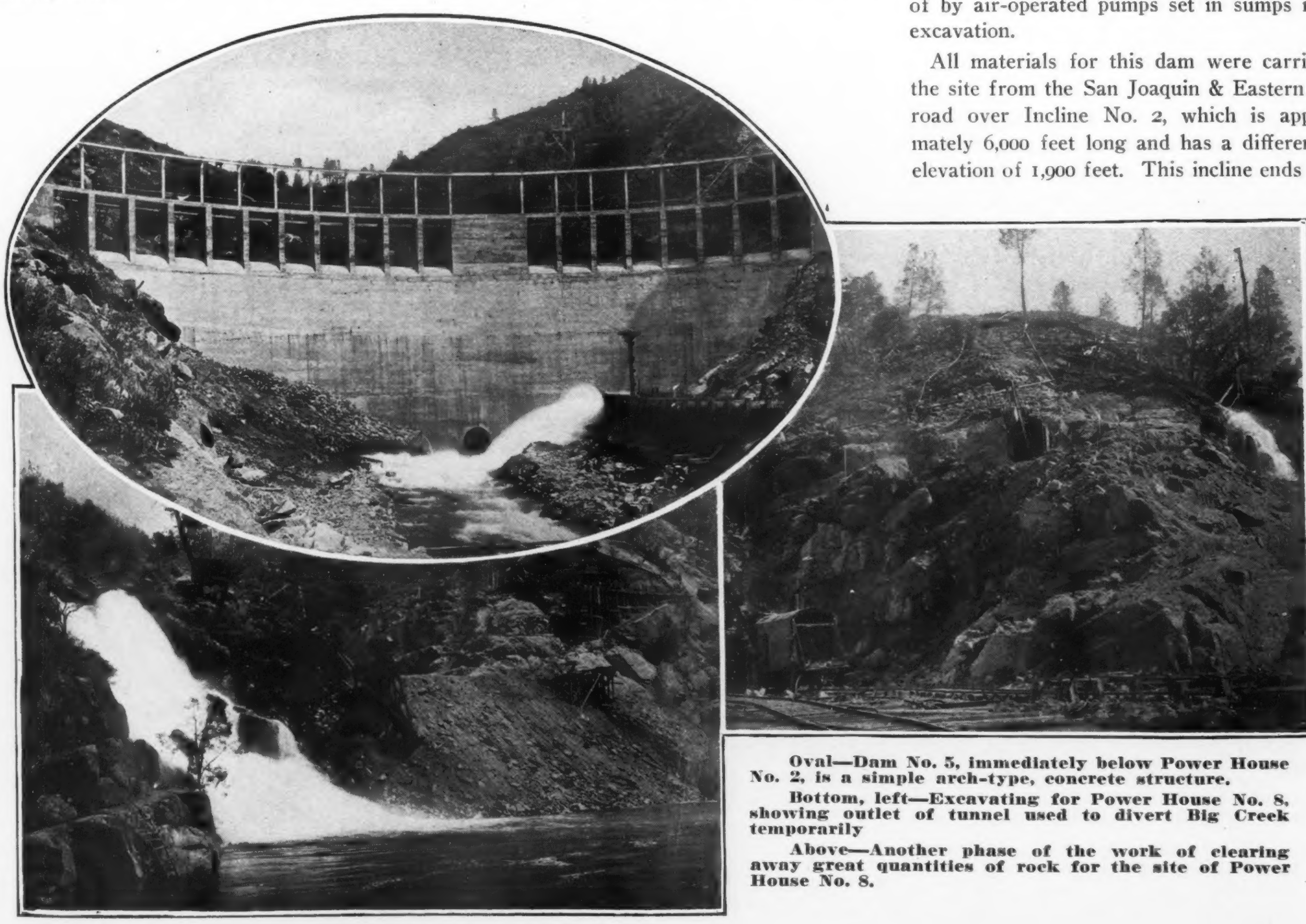
The dam forming the regulating reservoir, Dam No. 5, is a simple arch-type, concrete structure. From the lowest point of excavation in the center of the channel to the floor of the operating platform is a matter of 80 feet; the crest is 260 feet long; and the entire barrier contains approximately 3,800 cubic yards of concrete. Dam No. 5 has a curvature radius of 150 feet. The upstream face is vertical, while the downstream face has a batter or slope of 2½ in 12—the thickness of the dam at the spillway crest being 7½ feet and at the lowest point 23 feet. Nineteen 7-foot openings are provided for wooden flash gates which extend 6 feet above the permanent crest—the top line of the flash boards being at Elevation 2,945. This arrangement leaves just sufficient difference in elevation between the tops of the flash boards and the tailrace openings of Power House No. 2 to protect the tailraces against flooding, which would result in a loss of head in that plant.

The flash gates are controlled from an operating platform, at Elevation 2,950, by a hand-operated crane. This crane travels the entire length of the dam on an I-beam rail located 12 feet above the platform. Two electrically actuated 72-inch sluice gates are placed at the bottom of the dam. These gates are protected by rack bars, which are made of 30-pound rails, built on a 5 to 12 batter and spaced 12 inches from center to center.

During the construction of Dam No. 5 the flow of Big Creek was carried through the dam by means of a 5x7-foot wooden flume. A sack cofferdam, approximately 50 feet in length and 5 feet high at the intake, diverted the flow of the creek into the flume. Excavation on the dam site was started November 16, 1920. Air for operating "Jackhamers" was supplied by a compressor located in Power House No. 2; all blasting was done with 40 per cent. gelatine dynamite; and mucking, due to the limited amount and to the close quarters, was carried on by hand. The muck was loaded into 1-yard, steel side-dump cars, running on 18-inch gage track, and was unloaded alongside the creek channel a maximum distance of 400 feet downstream from the dam site. Leakage from the diversion flume was taken care of by air-operated pumps set in sumps in the excavation.

All materials for this dam were carried to the site from the San Joaquin & Eastern Railroad over Incline No. 2, which is approximately 6,000 feet long and has a difference in elevation of 1,900 feet. This incline ends about

*Resident Engineer, Southern California Edison Company, Big Creek Construction, Big Creek, Cal.



Oval—Dam No. 5, immediately below Power House No. 2, is a simple arch-type, concrete structure.

Bottom, left—Excavating for Power House No. 8, showing outlet of tunnel used to divert Big Creek temporarily

Above—Another phase of the work of clearing away great quantities of rock for the site of Power House No. 8.

300 feet upstream from Dam No. 5; and from this point a 24-inch gage incline ran to a trestle paralleling the upstream face of the dam at Elevation 2,950. A concrete mixing plant, consisting of a cement platform, gravel bin, concrete mixer and tower, was placed at the center of the upstream face of the dam. The tower, equipped with a 1-yard concrete skip, was 110 feet high; and from it the concrete was conveyed to the various parts of the dam by means of chutes. A small air hoist drew the cars from the warehouse platform over a narrow-gage incline, and storage-battery locomotives pulled them on the trestle. The hoist for the tower was operated by a 40-H. P. electric motor.

Form lumber was stored on a platform at the warehouse and was moved to the dam as needed over the 24-inch gage incline and trestle—the cement from the warehouse being handled in like manner. The sand and the crushed rock for the concrete were procured from muck taken from the outlet portal of Shaver Tunnel and stored in a pile about 300 feet upstream from the dam site. A narrow-gage incline tapped the lower edge of this pile, delivering the sand and rock to the mixing plant. The incline cars, which were operated by an electric hoist, were loaded by the aid of a hopper. The latter was kept filled by a small scraper that pulled the material from the upper end of the pile to the hopper. The placing of forms was started on March 2, 1921, and the first concrete was poured eight days later—the erecting of the forms just preceding the pouring of the concrete. Dam No. 5 required approximately 22,000 square feet of forms.

The main body of the dam up to the crest of the spillway was finished on March 30, 1921, and the balance, consisting of flash boards, piers, and an operating platform, was completed on April 25, following. After the spring run-off of that year the by-pass flume, carrying the waters of Big Creek, was removed; the sluice gates through the dam were opened; and the passage through the dam for the wooden flume was sealed.

The intake portal of Tunnel No. 8 is located about 400 feet upstream from Dam No. 5, and the crew that had built the latter was put on the tunnel-intake job. The intake is a reinforced-concrete structure, 40 feet high, that supports the steel rack bars which divert spoils, etc., from the tunnel. As it is believed that the water from this tunnel will not have to be diverted, except perhaps at infrequent intervals, gates for this purpose were not deemed necessary. However, stop-log grooves are provided to make it possible at any time to enter the tunnel in the event that the water cannot be drawn down from the regulating reservoir through the two 72-inch sluice gates in Dam No. 5. A matter of 2,260 cubic yards of granite was excavated from the side of the canyon for this intake structure, which contains approximately 460 cubic yards of reinforced concrete.

To facilitate transportation, a road had to be constructed from an existing roadway, which parallels Tunnel No. 8, at a point about 300 yards west of Adit No. 1 to the site of Power House No. 8. This road, shown on the accompanying map of Project No. 8, has a maximum grade of 10 per cent. and more or less parallels Big Creek. Clearing the path and laying the air and the water lines for roadbuilding was commenced on October 5, 1920, and about 30 days later a Marion No. 21 revolving steam shovel, with caterpillar traction, was placed on the job. This shovel was operated by compressed air. From November 4 to December 8, the shovel finished 6,000 linear feet of 15-foot roadway leading to the site of Camp 33—a total of 12,500 cubic yards of earth and loose rock being excavated in that interval. In the execution of this work, most of the ground had first to be loosened by blasting.

On November 26, 1920, before the road was completed, construction was begun at its terminus of a 300-man camp—Camp 33—which was substantially ready and fully occupied 24 days later. Until April 15, 1921, all mail and supplies for Power House No. 8 were delivered from West Portal—on the San Joaquin & Eastern Railroad—over Incline No. 2 to Camp 7, whence they were carried by truck or wagon over the new road. But thereafter an auxiliary standard-gage incline was operated between Camp 32 and the site of Power House No. 8. This incline greatly facilitated the delivery of materials and supplies during the rainy season when heavy haulage by way of the new road became impracticable.

Owing to the nature of the country, the delivery of materials and supplies, especially of the heavier permanent power-house equipment, proved to be somewhat of a problem. After a thorough study of various schemes it was decided that the most practical and economical method would be to extend the incline from Camp 32 all the way to the San Joaquin & Eastern Railroad—an additional distance of 7,800 feet and 1,800 feet higher in elevation. The total length of Incline No. 8 is 10,800 feet, and the difference in elevation between the railroad and the power house is 2,470 feet. A new station, named Feeney, was established on the railroad with the requisite yards, warehouses, etc.; and Camp 42 was located there.

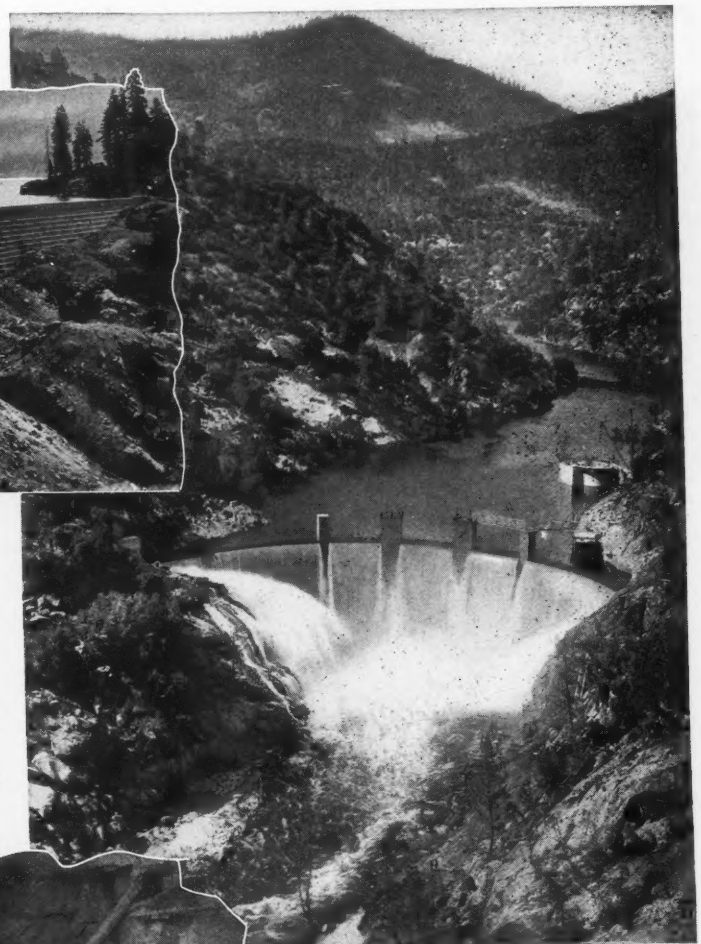
As shown on the accompanying map, it was necessary to put several curves in the incline to conform to the topography of the mountains. The grades vary from a minimum of 6 per cent. to a maximum of 50 per cent. The incline is provided with a hoist driven by a 250-H.P., variable-speed motor; and the main brake is of the hand-operated post type, and is at one end of the drum. The hoist is also fitted with an auxiliary, automatically operated solenoid brake. The incline cable is 1½ inches in diameter and consists of 6 strands of No. 19 plow-steel wire. Using a single line, the outfit has a rated capacity of 35 tons—in other words, a 15-ton "strong back" or incline car can carry a 20-ton load. For the heavier loads, requiring a double line, an 84-inch sheave is provided that travels on a small car between the cable and the main car. By this means a maximum load of 70 tons was handled, or 55 tons on a 15-ton car. These loads do not include the weight of the cable.

Owing to the time involved in making the trip between Camp 42 and the power house, an auxiliary 200-H.P. hoist was located at the intermediate storage yard at Camp 32. This hoist handled the penstock pipe and the concrete materials for the penstock anchorages and the power house. The aggregates for the concrete were produced by a crushing plant adjacent to the incline.

As a precaution against surges due to changes in flow in the penstocks, a steel forebay, 35 feet in diameter and 95 feet high, is located at the outlet of Tunnel No. 8—described in the preceding instalment—and at the beginning of the penstock. A steel pipe, 18 feet in diameter, connects this forebay with the outlet of the tunnel. The latter is lined with concrete at that point to take care of the warped section between the tunnel and the inlet end of the 18-foot pipe. The surge tank has trash racks and 3 penstock outlets: one, 8 feet in diameter, is utilized for the present unit, while the two others, each 10 feet in diameter, are provided for future units. The officials of the Southern California Edison Company are of the opinion that the progress made in designing turbines and generators may warrant them in installing at some future day units of greater capacity than the initial one.

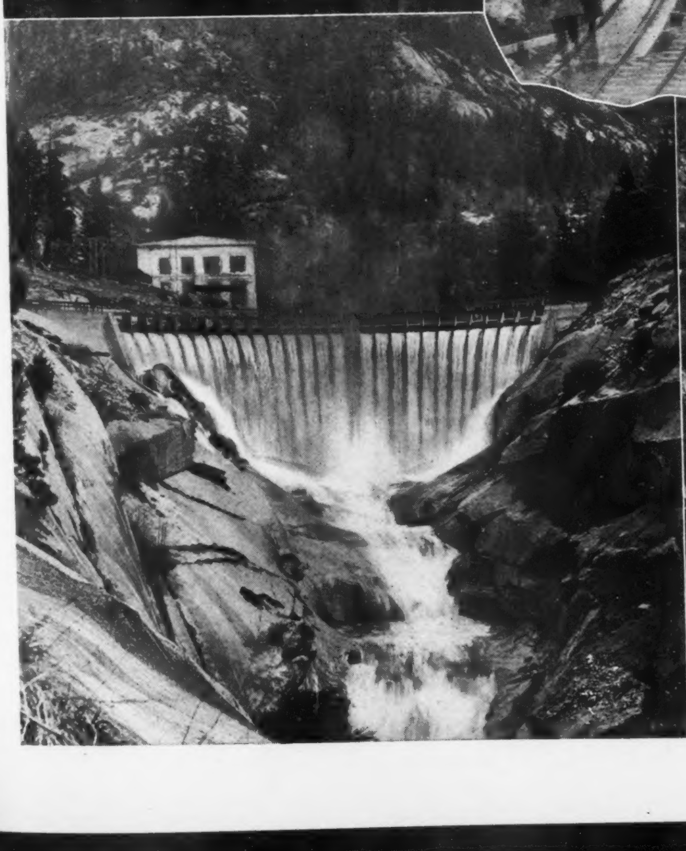
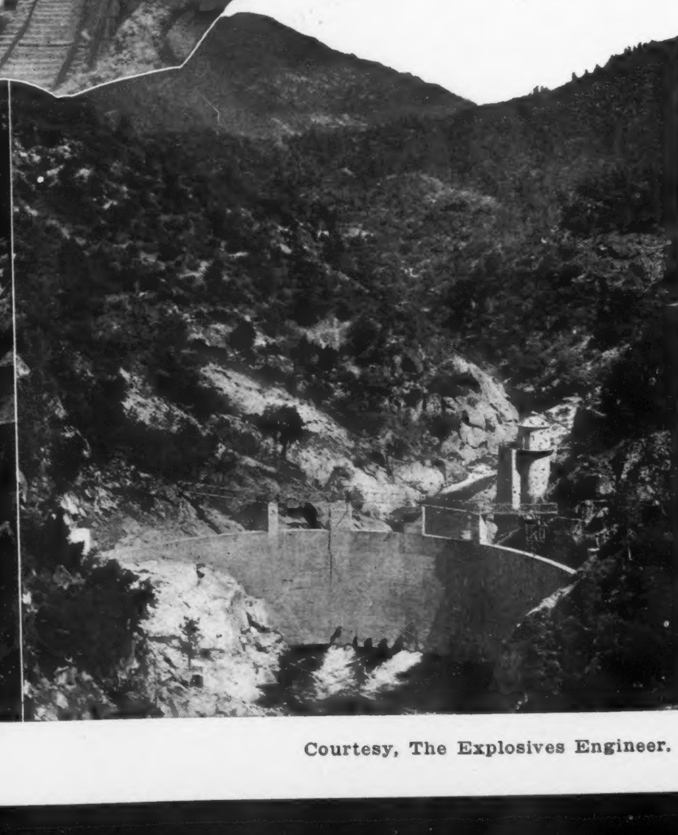
There is an 8-foot gate valve between the surge tank and the present penstock that is electrically operated from the power house through remote-control apparatus; and a 36-inch diameter standpipe on the penstock below this gate provides an air vent. The surge tank is set on a concrete foundation, and has a 24-inch drain valve in the bottom. Owing to delay in the delivery of structural steel, this tank was not completed until several months after Plant No. 8 was put in service. In the interval, the power house was operated as a flow line instead of under pressure, with an accompanying loss of head of practically 50 feet. By that time the concrete bulkhead for the purpose of closing the adit about 1,300 feet back from the tunnel outlet had been constructed to one-half the tunnel height, thus providing a spillway to take care of surges in the penstock. The water back of Dam No. 5 was maintained at the level necessary to keep the tunnel working as a flow line.

The excavation for the penstock was begun on March 17, 1921, at the lower end of Power House No. 8, immediately above the site of the Johnson valve, and was cut deep in solid granite. Drilling was done with "Jackhamers"; and the muck was removed partly by hand and partly by steam shovel and hydraulic sluicing—the same crew that had been employed on the power-house excavation carrying on this job. No more excavating was done on the penstock until April 22 following, when work was started at the upper end near the forebay. With the exception of the lower 600 feet, the ground cleared away consisted mostly of dirt with some boulders and hardpan in the deeper cuts. Where necessary, churn drilling and black powder were resorted

SOME STRIKING VIEWS OF BIG CREEK PROJECT

The outstanding features of the Big Creek undertaking are the linking by rock-hewn tunnels of several mountain lakes and the erection of a number of hydro-electric stations for the generation of great blocks of electrical energy. By 1935 the Southern California Edison Company will be in a position to distribute throughout the southern and central parts of the state quite 1,500,000 H.P. daily.

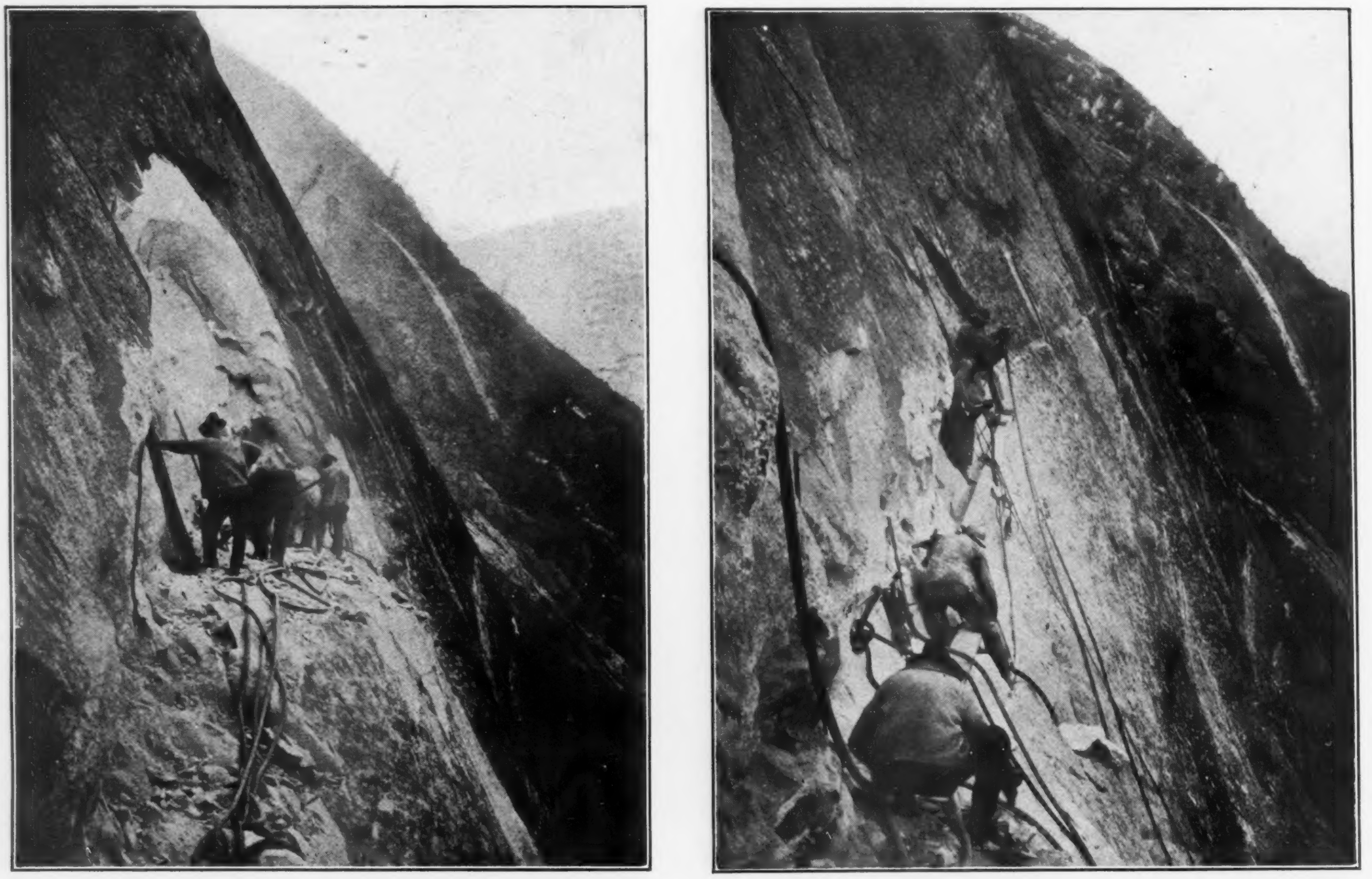
Courtesy, The Explosives Engineer.

to for loosening the material. Mucking was performed by means of a Bagley scraper and by teams with Fresno scrapers, while some trimming was done by manual labor. The upper 200 feet were excavated by a steam shovel operated by compressed air. A total of 10,781 cubic yards had been removed by May 22, 1921, when the first concrete was poured for the footings of the concrete saddles for the penstocks. On June 9, the first section of pipe was rolled into place; and by June 22—within thirteen days, to be exact—all concrete piers were finished and the piping was in the ditch. Riveting on Anchor No. 3 centers. A layer of 2-ply roofing paper has been placed between the piping and the concrete so that the former is free to move on the saddles. Expansion joints are located about half way between each set of anchors to provide for any movement in the pipe due to temperature changes. Penstock No. 8 is not back filled. A 72-inch Johnson valve at the lower end of the penstock controls the flow to the turbine.

The site of Power House No. 8 is at the junction of Big Creek and the San Joaquin River on the south bank of Big Creek directly over the channel. It was therefore necessary to divert the flow of Big Creek before excavating for the foundations of the power house. This was done by driving an 8x8-foot diversion tunnel through a short ridge on the north side of the creek. The intake for this tunnel is about 500 feet upstream from the power-house site and the outlet is on the San Joaquin River approximately 200 feet upstream from the mouth of Big Creek. Work on the diversion tunnel was started December 10, 1920—the first ten days being spent in installing air and water lines; in constructing trails and powder houses; and in opening a cut at the outlet end. The actual driving of the tunnel was begun at the outlet end on December 20. The open cut for the intake portal was commenced ten days later—driving of that particular heading beginning January 5, 1921. The two headings met on January 27, after 511 linear feet of tunnel had been driven or 1,220 cubic yards of solid rock had been removed—representing an average progress of 8.7 linear feet per day for each heading. A total of 59 working days was spent on both headings. About 80 linear feet of this tunnel was in soft material, which necessitated concrete lining. The outlet portal was also lined for a distance of approximately 15 feet, requiring 135 cubic yards of a 1:3:5 mix of concrete. A sack dam, about 10 feet high and 80 feet long, was built across Big Creek to divert its flow into this tunnel—the water being first allowed to run through on February 5, 1921.

Excavating for Power House No. 8 was begun on January 8, 1921, at which time a crew of laborers started pick-and-shovel work at Elevation 2,290, which is something like 75 feet above the foundation of the generator building. Between February 1 and 14, hand labor was supplemented by hydraulic sluicing—a 12-inch pipe line having been run on grade from Big Creek into a storage tank on the ridge above the power-house site. A 2-stage, 6-inch centrifugal pump delivered water from this tank to a hydraulic monitor with a 3-inch nozzle. By this method the surface dirt and loose muck were sluiced from the site—a total of 2,600 cubic yards being disposed of in that way.

On February 14, a Marion No. 21 revolving steam shovel, using oil for fuel, commenced stripping at Elevation 2,205—drilling with "Jackhamers" and blasting with 40 per cent. dynamite preceded this to loosen the material.



Courtesy, The Explosives Engineer.

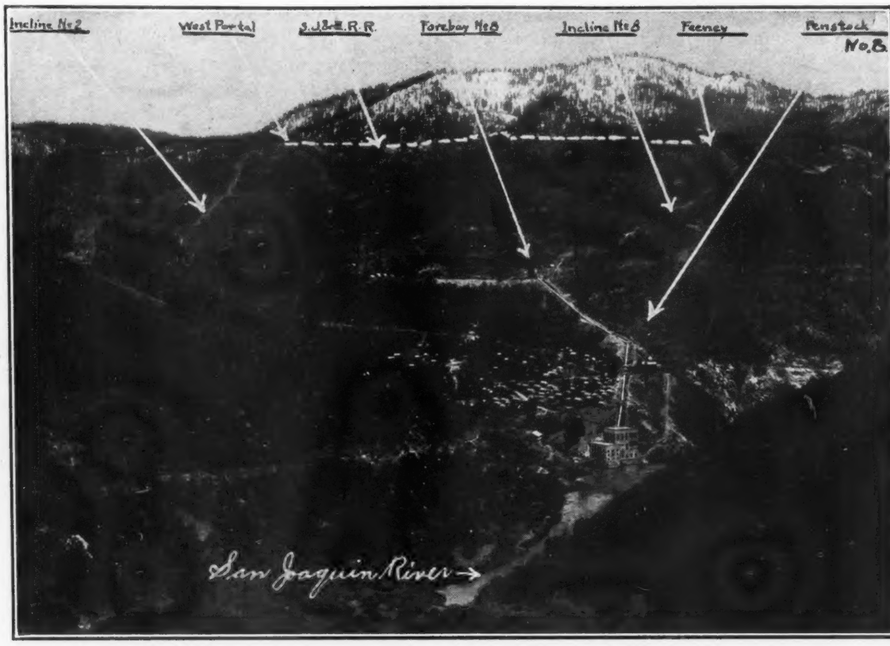
In pushing forward the Big Creek project it has been necessary to build roads around the faces of steep cliffs. Here we see some phases of this risky work which has been made possible by the pneumatic drill and dynamite.

was then promptly begun. From that time on work progressed in both directions.

Measured on the slope from the surge chamber to the Johnson valve at the power house, Penstock No. 8 has a length of 2,713 feet. The static head on the penstock varies from 47 feet at the upper end to 715 feet at the power house. To take care of this difference in head, the pipe at the surge tank is made of 3/8-inch plate and is 8 feet in diameter, while at the power-house end it has decreased to 6 feet in diameter and is 1 1/8 inches in thickness. The upper 506 feet of piping is riveted, and the remaining 2,207 feet is lap welded. There are five vertical and horizontal angle points in the length of the penstock, and each of these angles is held in place by large reinforced-concrete anchors. Between these anchors the pipe is supported on concrete saddles spaced approximately 20 feet between

This work progressed eastward up the dry bed of Big Creek—the muck being removed by Western 6-yard side-dump cars run on standard-gage track by means of an air-operated hoist and cableway. During the last fourteen days of the month 3,200 cubic yards of solid granite were drilled, blasted, and got rid of.

At that time it became evident that additional equipment would be necessary in order to complete the excavation within the specified period. Owing to the heaviness of the rock to be handled, a Marion No. 40 steam shovel, burning oil, replaced the No. 21 model on November 13—the latter being moved to Elevation 2,250. From that bench it took care of the upper part of the power-house excavation—throwing most of the muck down onto the lower bench where the No. 40 loaded this material, together with its own muck, into 6-yard dump cars. The surface or decomposed granite was drilled with "Jackhamers"; and No. 248 "Leyner" drills were used on the hard gray granite encountered well-nigh throughout the lower foundation area.



Comprehensive view of Power House No. 8 and the associate development.

By March 18, the work of excavating for the power house had been finished, and by April 30, the excavation for Unit No. 1 had been virtually completed. A total of 24,400 cubic yards of rock was removed—10,000 cubic yards for the initial unit and 14,400 cubic yards for Units Nos. 2 and 3. Although the building for only Unit No. 1 has so far been constructed, it was necessary to make the foundations for all three units at one and the same time in order to avoid seriously damaging the first structure later on. This part of the development was accomplished in 130 days; and the actual work of blasting for the excavations required about 10½ tons of Hercules 40 per cent. gelatine powder, 4,000 electric exploders, 16,000 feet of fuse, and 4,000 blasting caps. The average length of haul for the disposal of excavated material was approximately 300 feet.

Form work for the foundation walls and the columns was started immediately upon completion of the excavation; and the first concrete was placed May 12, 1921. The aggregate for the concrete was produced from the hard, gray-granite tunnel muck procured from Camp 32. The output of the crushing and screening plant was delivered into storage bins, located on Incline No. 8, from which the material could be loaded directly into the incline cars. These, in turn, carried the material right into the storage bins at the power house. An air hoist was used to elevate the concrete in a tower which, together with the mixing plant, was situated on the slope of a mountain. A large portion of the concrete was placed from this tower by chutes, and the balance was delivered by buggies to all parts of the building.

Power House No. 8, as shown in an accompanying illustration, really consists of two structures: the lower or generator building, which houses the generator set of the initial unit with the associate pumps, oil storage tanks, and switchboard, and the upper or transformer building where are installed the 220-kv. transformers and switches. The floor of the generator building is at Elevation 2,250. From that point on down, the building is of reinforced concrete, while the superstructure is a combination of structural steel and reinforced concrete. The transformer building is of structural steel and reinforced concrete throughout. The generator building is made up of 3,015 cubic yards of concrete and the transformer building of 1,460 cubic yards—making a total for the power house of 4,475 cubic yards, all of which was placed from May 12 to September 1, 1921. On June 20, 1921, as soon as the foundation had progressed far enough, the installation of the turbine was commenced. This unit is a 30,000-H. P., single-runner, vertical turbine of the improved Francis-Pelton type, made by the I.P. Morris Company, and is designed to operate at 428 revolutions per minute under a 680-foot effective head. The runner is set at Ele-

Two of the chain of generating stations on Big Creek. Above—Power House No. 2. Right—Power House No. 8 in course of construction.

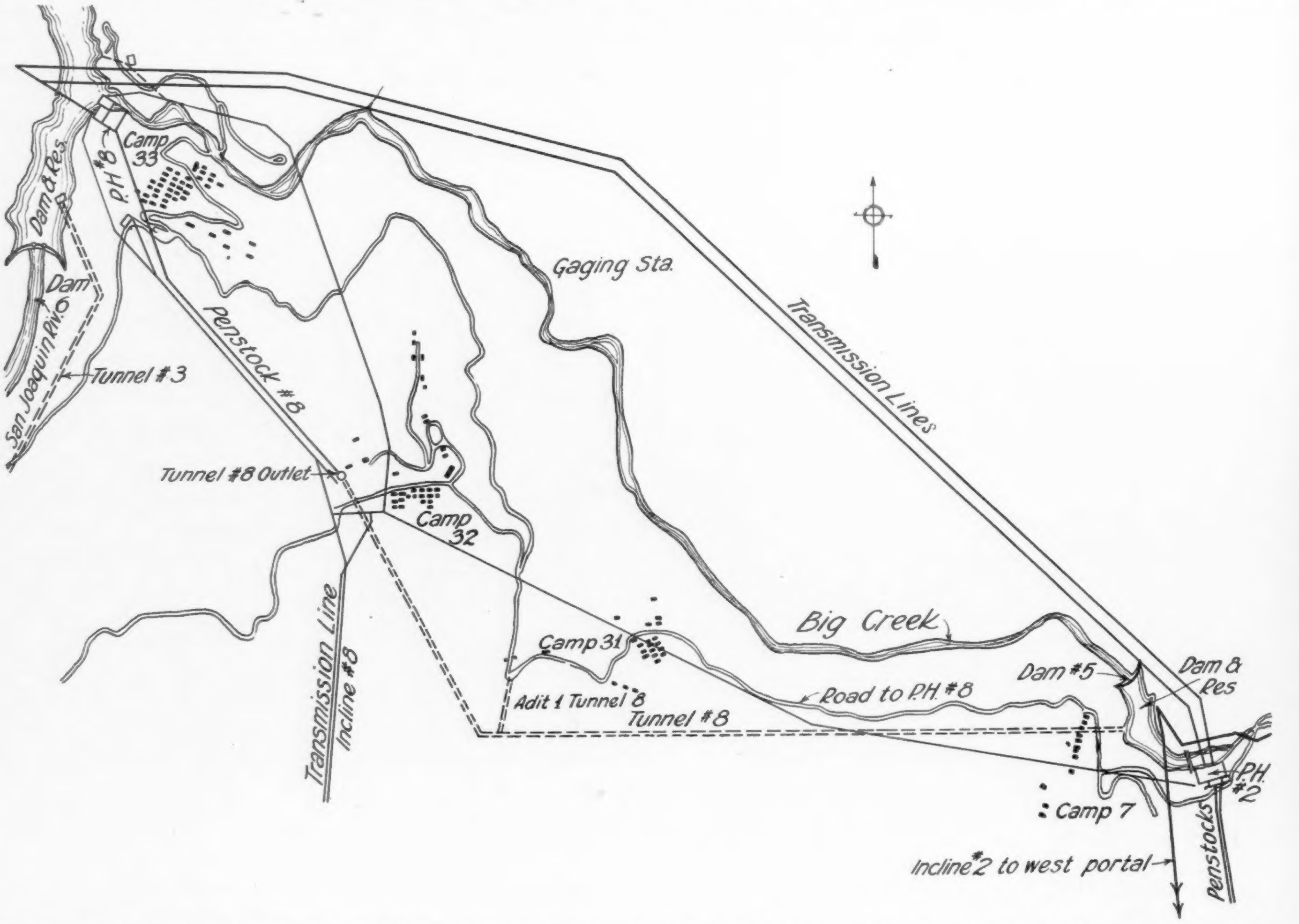
vation 2,230. The generator—a 22,500-kilowatt machine manufactured by the General Electric Company—is direct connected to the shaft of the turbine. It is 17½ feet in diameter and 12¼ feet in height from the floor to the base of the upper or thrust bearing. The exciter is located above the generator on top of the main shaft.

Owing to the load limitation of the incline, the generator stator was shipped in halves and was assembled on the floor of the station. The windings, which were forwarded separately, were then installed. The generator rotor, consisting of five separate rings, was also sent "knocked-down" and was shrunk onto the generator shaft at the power house. This machine has a generating voltage of 11,000, and this is stepped up to 220,000 volts through the transformers in the adjoining building. The transformers, also manufactured by the General Electric Company, are of the indoor type and are connected to two sets of 220,000-volt buses placed directly above the transformers. The buses are connected to two sets of 220,000-volt oil switches which are on the two upper floors of the transformer building. Until May, 1923, the No. 8 plant was operated at 150,000 volts. Then the entire Big Creek system of the Southern California Edison Company was changed over to 220,000 volts—the first commercial use of this high voltage in the history of the world.

Just ninety days after the pouring of the first concrete, on August 10, 1921, to be exact, water was allowed to flow into the penstock and the unit was turned over. Three days later, this plant was generating power—thus establishing a record for this kind of construction. This achievement was made possible by working both day and night—two shifts being employed on the building and three shifts on the installation of the equipment.

The power generated at this station is tied into the main 220,000-volt transmission line by way of Power House No. 2. This linking up necessitated the erection of two separate, parallel, single-circuit, steel tower lines similar to the main Big Creek transmission lines. From Power House No. 8 to the roof of Power House No. 2 this tie line is 9,340 feet long, and it required a total of 27 transmission towers—13 on the west line and 14 on the east line. Clearing the right of way for the transmission line was commenced May 1, 1921. A month later the first structural steel arrived, and distribution was begun. The work of erection started from Power House No. 2, and by July 22 all towers were in position and conductors strung. Due to the delay in the arrival of the high-tension switching equipment it was necessary to make temporary connections at Power House No. 8. The first line was energized on the night of July 31, when 160,000 volts were backed through the wires from Power House No. 2.

(To be Concluded)



Map covering the principal topographical and the main engineering features of Development No. 8 of the Big Creek hydro-electric project.

WARNING TO MOTORISTS

MOTORISTS should remember that it is imperative to guard against the deadly hazard to which they are subjected when automobile engines are permitted to run in closed garages. Despite the fact that articles are repeatedly published that lay great stress on the extremely poisonous properties of carbon monoxide—one of the products formed when gasoline is consumed in an automobile engine, cases of asphyxiation continue to be reported when cold weather prompts the closing of garage doors and windows in order to retain heat.

Four-tenths of one per cent. of carbon monoxide, that is, 4 parts per 1,000, will kill an ordinary man in one hour, and a higher concentration will prove fatal in much less time. Automobile tests made at the Pittsburgh experiment station of the Bureau of Mines show that the amount of carbon monoxide present in the exhaust gases varies from 2.4 to 9.5 per cent. and, consequently, that the air in a closed garage will reach the danger point in a very few minutes.

It is a common practice among motorists on cold days to allow the engine to idle for five or ten minutes before leaving the garage so as to warm up the oil and the cooling water. This is an extremely dangerous practice; and cases are reported not infrequently where the driver is found dead at the wheel. If it is desired to warm up the engine, all windows and doors should be opened or, better still, the car should be driven into the open air where the toxic exhaust gases are quickly dissipated.

Something About the World's Biggest Mining Camp at Butte

From the 40 Mines in This District of Montana 100,000,000 Tons of Ore Have Been Removed in the Last Half Century

BY GEORGE H. DACY

HISTORIC among American metal mining regions; romantic in tales of early adventure; prolific as a producer in the course of the last 50 years of more than 100,000,000 tons of valuable ore worth in excess of $1,600,000,000, Butte, Mont., has the distinction of being the largest mining camp in the world. This busy western town has at present a resident population of 48,000—one-fourth of which is employed actively in its two-score leading mines.

The mention of Butte should be enough to thrill any American imbued with the spirit of adventure, for that notable camp has been epochal in the work of metal mining and in generally stabilizing an industry characteristically replete with difficulties. Butte is outstanding as a center of subterranean riches; and its mines, when operating at capacity, employ as many miners as Colorado, Utah, and New Mexico combined and more than one-half the number in the workings of California, Nevada, and Arizona.

Since the inception of the Butte mining camp over 50 years ago, more than 7,200,000,000 pounds of copper, 625,000,000 pounds of zinc, 325,000,000 ounces of silver, 1,610,000 ounces of gold, and 42,000,000 pounds of lead have been recovered from that storehouse of mineral wealth. Ore reserves now blocked out indicate that a production worth at least $50,000,000 can be maintained annually for many years to come, except when operating costs mount too high or selling prices drop too low.

The region around Butte consists of a granitic uplift through which several series of veins run in an easterly direction. The main producing lodes of copper and of zinc are parallel—being up to several hundred feet apart—and strike nearly due east and west, while the other productive intersecting veins bear southeast. These lodes vary from a few inches to 150 feet in width. The veins of greatest width are generally above the 2,000-foot level, although practically all the granite throughout one section of the camp is mineralized below the 2,000-foot level. The surface in the northern part of the district has yielded an abundance of silver ore, while rich deposits of zinc lie at some depth beneath. South of the zinc belt is the copper zone, which underlies the main business section of Butte. Near by is a comparatively recent development rich in shallow deposits of zinc and manganese. About two miles distant is an area that contains large amounts of silver-lead ores at a depth of approximately 1,000 feet.

Vertical shafts predominate in the Butte mining camp—the original intention being to sink in the footwall and to crosscut to the vein. However, as veins with a dip of about 70 degrees parallel one another, frequently having intervals of a few feet or less between them, the footwall of one lode is the hanging wall of another. There are few shafts that do not intersect one or more veins. Consequently, shaft movement is common and, even though it involves considerable expense, it is unavoidable in many cases.

It has been the practice at Butte to crosscut from the shaft to the lode at intervals of 100 feet vertically until a depth of 1,500 feet is reached, and from thereon down to have the levels 200 feet apart. Crosscuts and drifts are about five to six feet wide and from seven to eight feet high, and are timbered only where necessary to support overlying material. When a vein is cut the drifting is generally done in the vein, although laterals are sometimes driven in the footwall, at distances of from

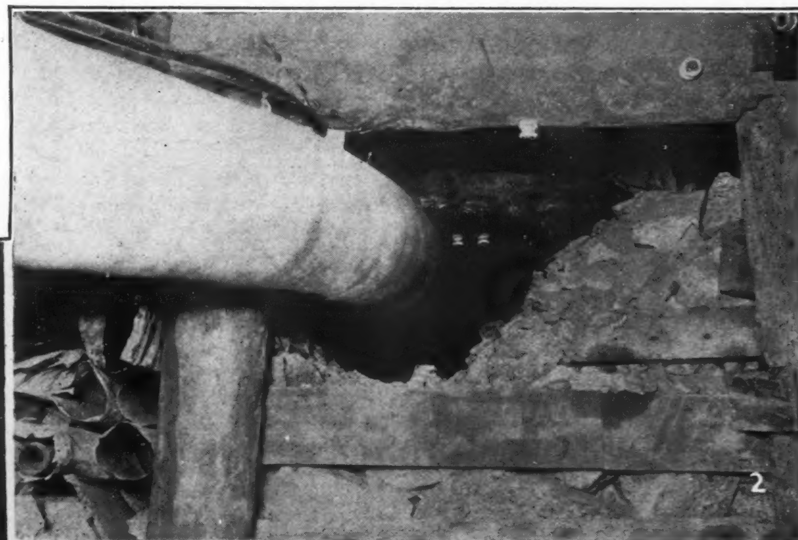


Fig. 1—Small electrically driven fan and canvas pipe installed to improve ventilation in a drift in one of the leading metal mines.

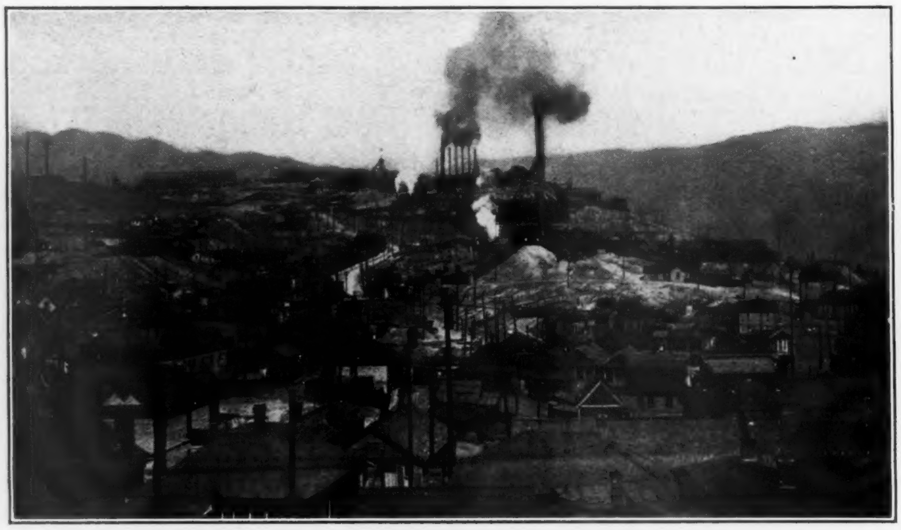
Fig. 2—Canvas pipe turning a corner. Experience has proved tubing of this sort to be cheaper and easier to install than metal pipe and less heating to the air because of reduced friction.

30 to 50 feet from the vein, with intermittent crosscuts; or drifting may be done in the vein to be paralleled later by laterals in the footwall with the expectation of readily keeping the laterals open—the maintenance of the drifts being difficult.

In practically all the Butte mines, back stoping is used with some method of back filling. Usually, square-set timbering is placed coincident with the removal of ore, and this is followed by back filling between timbers with waste or low-grade ore sorted from the stopes or trammed to convenient chutes from development crosscuts. Much experimenting has been done to limit the consumption of timber; and in this work the tests with the Rill system, in which little or no timber is used except in manways or chutes, has been most successful. Back filling keeps pace with ore removal; and the mucking of ore or waste is held down to a minimum. Before stoping begins, raises are generally driven for from 30 to 50 feet along the vein or occasionally in the footwall

to the level above. Where the entire lode samples 3 per cent. copper or more, little or no sorting is done except, perhaps, to gob large boulders of waste.

Wet drills are used entirely in drifting and in crosscutting—all this work being done by contract. For an ordinary drift or crosscut face in solid rock something like a dozen holes are drilled about five feet deep and loaded with from seven to ten sticks of 40 per cent. gelatine explosive. At Butte, wet stopers are preferred for stoping—no dry-piston machines are used. The compressed air that drives the pneumatic tools has a pressure of 90 pounds per square inch at the surface, and this pressure drops to 70 pounds at the working places. In the newer operations, electric locomotives, taking a 250-volt current from a trolley, are commonly employed; but some of the mines are changing over to storage-battery locomotives, and are doing this to advantage. In the older sections that are about worked out the primitive method of mule haulage is still in vogue.



This picture of Anaconda Hill shows the locations of some of the richest and most productive mines at Butte.

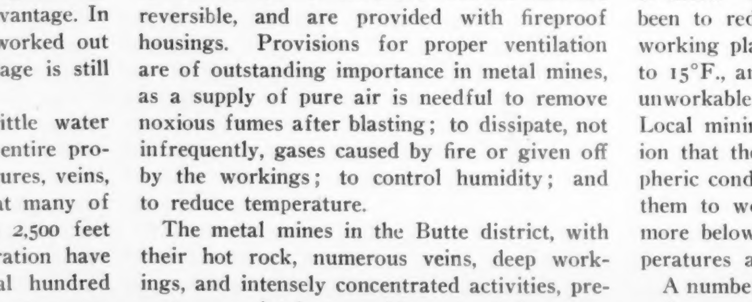
Strange to say, comparatively little water enters the mines even though the entire productive area is badly broken by fissures, veins, and faults and despite the fact that many of the mine workings are more than 2,500 feet deep. The 40 mines now in operation have open underground passages several hundred miles in length, and yet the total water seepage amounts to less than 7,000 gallons per minute. Over one-half of this is pumped from two of the most important mines which serve as sumps. In the drifts underground the water is conducted in troughs, which are ordinarily placed alongside the tracks where the injurious effects of moisture on rails, spikes, and iron turn sheets may be prevented.

Some years ago, the Anaconda Copper Mining Company installed several hundred electrically driven suction and blower fans to facilitate efficient mine ventilation. These helped to remove approximately 1,300,000 cubic feet of air per minute, and provided each miner with about 250 cubic feet of air per minute. More recently, the Anaconda Company authorized the expenditure of approximately $3,000,000 to improve the system of ventilation. As a result, the size of each electric fan has been more than doubled, so that the total capacity now exceeds 3,000,000 cubic feet of air a minute. All the upcast shafts have been smooth lined while the downcast shafts have been gunited. Further, in order to prevent the spread of fire, the downcast shafts have solid concrete sections every 100 feet. These sections are 10 feet in height and are carried back to the rock wall of the shaft. All the fans are reversible, and are provided with fireproof housings. Provisions for proper ventilation are of outstanding importance in metal mines, as a supply of pure air is needful to remove noxious fumes after blasting; to dissipate, not infrequently, gases caused by fire or given off by the workings; to control humidity; and to reduce temperature.

The metal mines in the Butte district, with their hot rock, numerous veins, deep workings, and intensely concentrated activities, present many intricate problems to their operators that call for the utmost engineering skill. The mining companies have already done much to better ventilation underground and are continuing their efforts to improve the air conditions for the miners. The mine-dust menace has practically been overcome by the introduction of the wet drill, which is now being used for all drilling operations; by the installation of water lines for sprinkling the working faces in the mines; and by increasing the flow of air which, incidentally, helps to carry off the dust as it is formed.

At present, most mines in Butte employ at least one man whose duty it is, among other things, to see to it that the ventilating machinery is functioning properly. Latterly, the average volume of air delivered daily to a Butte mine has been increased 50 to 200 per cent. or more. The results of this betterment have been to reduce the mean temperature in the working places of some mines as much as 10 to 15°F., and to make other previously almost unworkable places bearable for the miners. Local mining companies are now of the opinion that they can produce satisfactory atmospheric conditions underground that will permit them to work ore bodies lying 5,000 feet or more below the surface, where the rock temperatures are from 115 to 120°F.

A number of the mines have conducted interesting tests to determine the air flow and how the smooth lining of shafts affects the velocity and the volume of the air. One of the deepest shafts was smooth lined with boards, gunite, and concrete to the 3,000-foot level, with the consequence that the air flow was increased from 55,000 to 85,000 cubic feet per minute without necessitating any changes in the ventilating equipment. Another mine built three test shafts. One model was rough timbered; another had a smooth-board interior; and the third, made of concrete and circular in cross section, was given a smooth inner surface. Each of the models was 150 feet long. They were put side by side in an underground raise; and a small fan was provided that could be connected by the aid of a flexible hood to the top of each duct. Tests showed that the fan could force 1.91 times as much air through the smooth-board shaft as through the rough-timber affair and 3.31 times as much through the circular concrete duct.



The self-rotated wet stoper enables the miner to do his work effectually and with the least discomfort.

Wet drills of this type are extensively employed in the metal mines of Butte because they minimize the generation of rock dust.

Additional tests showed that canvas tubing has many advantages over galvanized piping for blowing air to blind ends by small, direct-connected electric motors and blowers, that is to say, a given quantity of free air can be forced through canvas tubing with 30 per cent. less power; it is easier and cheaper to install; and it can more readily be kept tight at the joints. Canvas pipe lines are very flexible, and can be made to turn corners of 60 degrees and more without the need of interposing elbows. One mine manager has invented a novel system of coupling the separate lengths and, likewise, a simple method of suspending the tubing. But, unfortunately, canvas deteriorates rapidly when exposed to stagnant and humid air. The dilute acids, found in mine waters, cause it to rot rapidly; and it is also inflammable. An experiment in one Butte mine revealed that ordinary cotton string lost about 30 per cent. of its strength by exposure for less than 24 hours to moist, noxious air having a temperature of 70°F. Several manufacturers are now conducting tests for the purpose of making the material non-inflammable; of retarding decay; and of rendering it resistant to the acid waters to which it might be subjected.

The speed of production of automobiles would seem to be more notable than the speed of the machines on the road. The offices of the Ford Company officially announce that from January 1 of last year to October 17 the output of passenger cars and trucks reached the grand total of 1,500,696—an increase of approximately 60 per cent. over the same period of 1922.

Deflated canvas pipe suspended in an untimbered crosscut. When distended this pipe serves to distribute ventilating air.

LONDON'S WATER SUPPLY

A RECENT editorial in *The Engineer* brings together some interesting data concerning the water supply of London, the world's metropolis, which embraces an area of 563 square miles and has a population of nearly 7,000,000. Only 35 gallons per capita is supplied every 24 hours—a rate far below that of New York City or Chicago. The daily consumption, however, would fill a channel 10 feet wide, 2 feet deep, and 375 miles long, which, if following a straight course north and south or east and west, would rival the length or the breadth of England.

Over three-fifths of the water comes from the River Thames; a little more than one-fifth from the Lee; and the remainder from several other sources. There are 1,147,000 separate services, which are maintained through 6,600 miles of mains. Practically all the water is pumped once—much of it more than that; and there are 276 main pumping engines for this work having a combined horse-power of 43,967. All the river water is filtered in 171 acres of filter beds. Nearly 5,000 persons are employed in the service of keeping London supplied with what is said to be the purest of water. For that reason, water-borne diseases are practically unknown in that capital.

The Rumanian government is planning to construct a canal from Cernavoda, on the River Danube, to Constantza, a well-known port on the Black Sea. This waterway, work on which is to commence this spring, will shorten the present route from the Danube to the Black Sea by 250 miles.

SUCCESSFUL TREATMENT OF CANADIAN TAR SANDS

IT IS claimed that methods have been perfected by which commercial products can be obtained from the Athabaska tar sands found in the Province of Alberta. A plant has been erected at Waterways, on the Great Western Railway, where experiments have been successfully conducted. Two processes are said to have been developed—one for separating the oils and the other for extracting the asphalt.

The crude oil obtained by the first method is of 19.3 Baumé gravity, while the asphalt extracted gives a large yield of the merchantable product, ranging from 15 to 25 per cent. of the raw sand. Owing to the small percentage of the lighter constituents and the presence of sulphur, the crude oil is not the most satisfactory for producing gasoline or kerosene; but the lubricating oil stands an extra low cold test, and is an excellent product for use in cold climates.

NOVEL PNEUMATIC CLUTCH OF MUCH PROMISE

A NEW TYPE of clutch, known as the Dickson pneumatic and invented by H. F. Scruby, has had its try out under service conditions, and it is claimed to work especially well where clutches of large horse-power are required—the horse-power increasing rapidly with the diameter of the clutch. The device is said to be readily adaptable wherever clutches are now in use, and especially serviceable where remote control is a feature, like in a ship propelled by a gas engine controlled pneumatically from the pilot house.

The clutch is very simple, consisting of two disks with conical faces, the disks being supported on a hub which is keyed to the shaft to be driven. The disks are free to move a limited distance longitudinally on pins carried by the hub; they are fitted closely on the hub at their inner circumference; and their outer edges are fastened together with a flexible, airtight connection so that the space between the two disks becomes an airtight receiver. By means of a feed collar, which is stationary while the rest of the clutch revolves, air can be fed into the space between the disks. On a quill, equipped with ball bearings or the ordinary babbitted bearings, is mounted a case which has a conical face similar to the face on the disks, and to this case is bolted a ring with a like conical face. The disks have their faces lined with cork or other friction material, and are so constructed that when the ring is bolted onto the case the disks, with their opposing conical faces, are enclosed between the case and the ring in such a manner that the case and the ring can revolve freely without touching the faces of the disks.

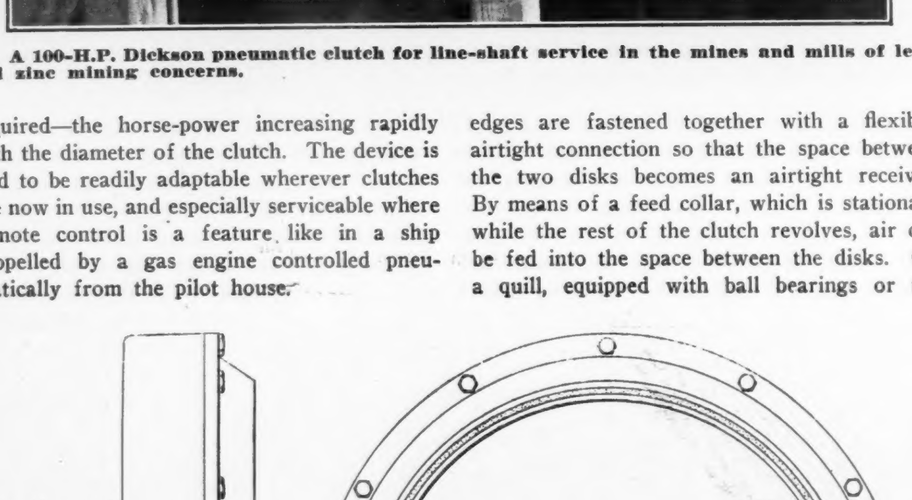
A 100-H.P. Dickson pneumatic clutch for line-shaft service in the mines and mills of lead and zinc mining concerns.

When air under pressure is admitted through the feed inlet to the space between the disks, the latter are forced apart, and the friction faces on the disks are brought into contact with the similar faces on the case and the ring. When the air is released, the disks are returned to normal position by means of springs carried on the pins through the hub. Due to the fact that the disks are of large area, very small pressures can be used to operate the clutch, one pound of air in a 30-inch clutch exerting a spreading power of 1,400 pounds. The maximum pressure required is three pounds per square inch. By employing surfaces of large area for friction surfaces, the friction material is never exposed to high pressures and is, therefore, assured a long life. Air pressure is supplied by means of a small rotary blower which is driven from the quill. A continuous supply of air is furnished, so that small leaks are thus taken care of in the event joints are not as airtight as they should be.

The Dickson pneumatic clutch has several outstanding features. There are no adjustments to be made—the air pressure, because it is evenly distributed over the surfaces of the disks, acts upon all points of friction with equal pressure. The clutch is controlled by a small air cock, which can be located to suit the convenience of the operator. We are told that the only wearing point is the bronze ring through which the air feeds into the clutch, and that after a year's service the wear on it was scarcely perceptible.

Elimination of adjustments and the advantage of remote control are features well worth considering; and when coupled with the long life of the friction material, due to light pressure and large area, a desirable clutch results. For the past eighteen months and more there have been tested out in the lead and zinc mines and mills of the Oklahoma mining district large horse-power Dickson pneumatic clutches, and, from all reports, they have given good service under the hardest conditions. Some of them have also been tried out in California, where they have proved their worth. After a year's practical work under the most unfavorable circumstances the clutches are said to have shown signs of little wear and tear.

There is also being made a clutch, without conical faces, using just the faces of the disks with friction linings and an air bag between the two disks. This clutch is also very satisfactory; but, in order to get the horse-power with straight faces, larger diameters must be used.



Sketch of the general features of the Dickson pneumatic clutch designed for use on automobiles or tractors.

Modern Tank Car is Industry's Bucket that Goes to the Well

Intended Originally to Transport Only Crude Petroleum, the Tank Car Now Carries Many Kinds of Liquids and Serves a Very Wide Field of Usefulness

By A. S. TAYLOR

THE tank car may fittingly be called the bucket of industry because this mobile container travels back and forth between the wells or other sources of needful liquids and the far-spread plants which utilize these commodities. Year by year the services performed by the tank car become more numerous and of increasing value.

There are probably something like 130,000 tank cars now tracing their busy ways wherever our railroads reach; and the materials carried by them would make a long list, indeed, if enumerated one by one.

In this article we shall tell something about the origin and the development of the tank car, what it means today to many departments of our industrial life, and how these adaptable vehicles are built.

THE TANK CAR was born all because barrels could no longer serve efficaciously for the economical hauling of petroleum in bulk. The tank car was the response of inventive genius to a demand for another and more commodious type of portable container. He did not realize it, but the man who first conceived the tank car blazed the way for a departure in railroad rolling stock which has proved of increasing usefulness with each succeeding decade.

Right here, a bit of history should be of interest. Oil was struck in Pennsylvania in 1859, and during that memorable year 2,000 barrels of petroleum were recovered from the various wells sunk. By 1865, the output had mounted until it totaled 2,498,000 barrels; and this sudden expansion introduced a serious problem—the question of an ample supply of containers at a reasonable cost. Naturally, the coopers were making hay while the sun shone, and were charging accordingly for their wares. At that time, crude oil was bringing the tidy sum of $6.59 a barrel, but the price of the barrel and the cost of carriage cut down considerably the profit to the seller.

At this point, six years after E. L. Drake showed the way to the enormous riches lying in the underground pools, someone suggested the adoption of wooden tanks, strengthened with iron hoops, as a substitute for barrels. As a result, a gondola or flat car was equipped by way of experiment with a couple of open-top vats, virtually big tubs, each capable of holding several hundred gallons of oil. Crude as that makeshift was it nevertheless proved fairly satisfactory, and it was found to be a long step forward in cheapening the transportation of oil from the wells to the refineries.

Improvement was possible, and after a few years the wooden tanks were supplanted by iron ones, the largest of these having a capacity of something like 3,000 gallons. It was only logical that iron tanks should be displaced by steel ones, and that the metal containers should assume the familiar cylindrical form surmounted by a dome to take care of the expansion of the oil while in transit and exposed to the heat of the sun or the higher temperatures of the summer season. The original adoption of iron tanks did away with the leaky, less sturdy, and highly inflammable wooden ones. Tank cars today range in capacity from 6,000 to 13,000 gallons, the average car holding, however, around 8,000 gallons.

While it is true that the majority of tank cars still serve the petroleum industry in its different departments, nevertheless a considerable percentage of these conveyances are now necessary aids to many other lines of productive endeavor. Factories or activities of the latter sort to which tank cars are now tributary have multiplied greatly in the last few years, and this has been especially noticeable since we began the upbuilding of an imposing domestic chemical industry. A point that is well worth remembering in gaging the usefulness and the value of the tank car is that the tank car, by providing a service of supply, permits the sources of some essential liquids to be established where they can be operated to the best advantage. In turn, consuming plants can be located where they may be run most economically and be within easy reach of their markets. For instance, low-priced electric current at Niagara Falls makes

Courtesy, The Pfaudler Company.

Phantom photograph of a refrigerated tank car for the transportation of fresh milk. The tanks are lined with porcelain.

it feasible to manufacture cheaply liquid chlorine, and this dangerous fluid is now carried broadcast in tank cars wherever textiles are bleached, paper pulp is whitened, and various oils are refined within our borders.

In numerous industries the barrel, as a unit of volume, is much too small to meet practical requirements and to permit of convenient handling; and in cases of this kind it is customary to have at hand storage tanks of large capacities that will insure unfailing and readily accessible supplies of raw, intermediate, and refined liquids. Experience has demonstrated that the tank car is peculiarly suited to the work of keeping these stationary reservoirs properly filled.

Courtesy, Petroleum Iron Works.

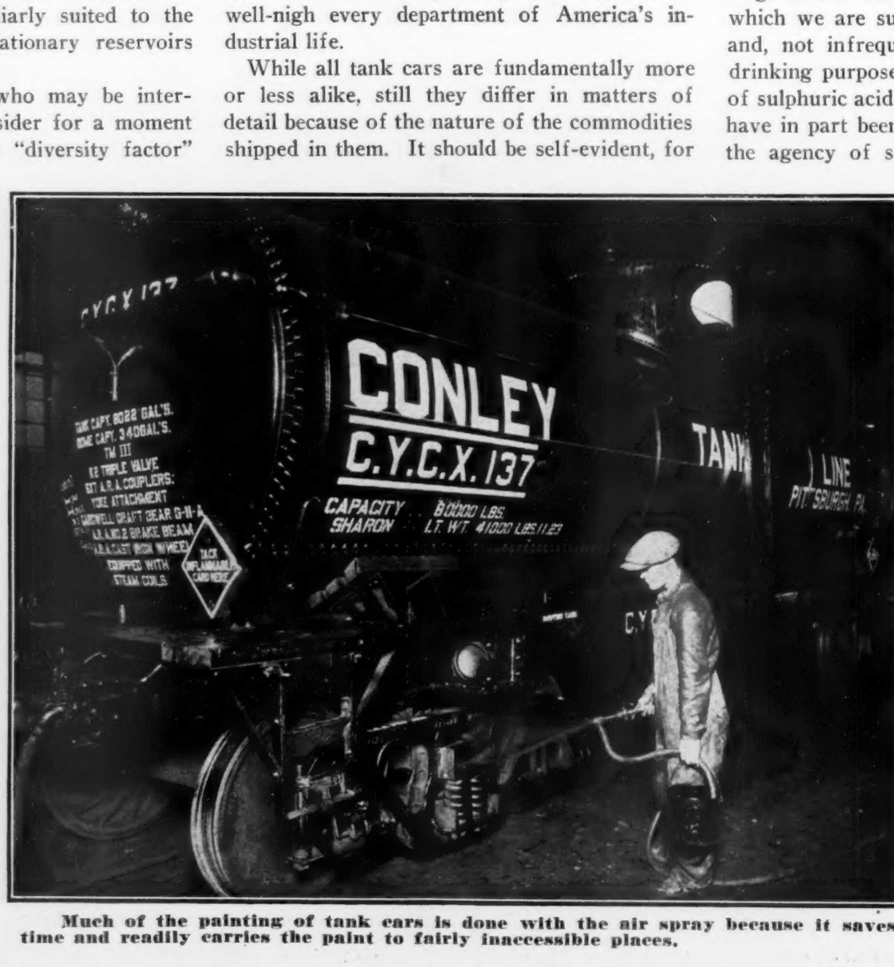
Power at Niagara Falls is used to produce various industrial chemicals, and this car serves to distribute some of them.

Here is a tank car adapted to the transportation of silica sand used in the manufacture of electric-light globes.

For the sake of those who may be interested in figures, let us consider for a moment what might be termed the "diversity factor" in the use of tank cars and let us see what is the percentage of employment in each service group. Petroleum and petroleum products utilize 69.1 per cent. of the cars; cottonseed oil, lard, lard oil, glycerine, candle grease, tallow, fats, etc., 5.9 per cent.; sulphuric acid, muriatic acid, liquid chlorine, oil of vitriol, etc., 3.3 per cent.; grain alcohol, wood alcohol, benzol, vinegar, etc., 3.4 per cent.; the transportation of molasses, syrup, glucose, and corn oil calls for 1.6 per cent.; the movement of coal tar, creosote oil, pitch, tanning extracts, turpentine, rosin, etc., requires 1.6 per cent.; and 15.1 per cent. of these adaptable vehicles are demanded for the carriage of miscellaneous commodities not already mentioned. Indeed, if we were to keep tabs on our tank cars in all their wanderings we should inevitably be put in touch with well-nigh every department of America's industrial life.

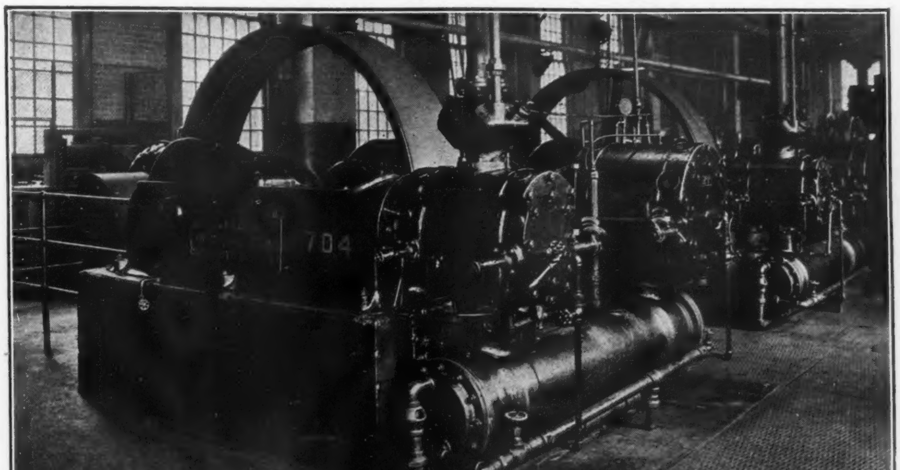
While all tank cars are fundamentally more or less alike, still they differ in matters of detail because of the nature of the commodities shipped in them. It should be self-evident, for example, that the transportation of weed-killing chemicals, of wine, of water, and of milk each imposes special requirements, and these must be met if the fluid is to arrive at its destination fit for use. Indeed, one is brought face to face with some curious or little known facts when one learns of the diversified precautions that have to be taken in handling many of these commercial liquids in transit.

Vast quantities of sulphuric acid are moved over our railroads every year. Sulphuric acid has been aptly dubbed the "dray horse of chemistry" because of the well-nigh endless uses to which it is put. The nickel-plated fittings in our bathrooms, the enameled tub in which we are supposed to take our daily dip, and, not infrequently, the water purified for drinking purposes have called for applications of sulphuric acid. The familiar soap and towel have in part been made what they are through the agency of sulphuric acid; and this corrosive fluid plays its part not only in the bleaching of the bristles of our hair brushes but, perhaps, in the composition of those brushes and their accompanying combs. To carry the story further, sulphuric acid has not unlikely had considerable to do with the manufacture of our tableware; and the syrup poured over our breakfast cakes owes its golden color to the refining effects of this same acid. We might go on indefinitely, but we are telling the tale of the tank car and not that of sulphuric acid.



Much of the painting of tank cars is done with the air spray because it saves time and readily carries the paint to fairly inaccessible places.

Curiously, sulphuric acid when diluted cannot be transported in iron or steel containers because the presence of water in the acid enables the latter to attack the metal. On



This battery of two Imperial, belt-driven compressors supplies much of the compressed air used in the Petroleum Iron Works and in the nearby affiliated plants.

the other hand, concentrated sulphuric acid will not eat iron or steel; and to ship sulphuric acid safely it is absolutely necessary that the car be sealed securely against the admission of rain or water from any source. As an added precautionary measure it is customary to coat the interior of tank cars designed for this service with an acidproof film of some sort. By way of contrast, we might mention that oxalic acid, nitric acid, and silicate of soda are shipped only in a dilute condition mixed with water.

Muriatic acid, which has many uses in industry, presents another problem to the tank-car builder inasmuch as it is destructive to steel. Cars designed for its carriage must be lined with wood; but as the acid will work its way through wood, dissolving the resin the while, it is necessary to interpose a thick, anticorrosive layer of asphalt between the metal and the wooden sheathing. Ammonia has an ever-widening field of service in various applications of artificial refrigeration or the manufacture of ice, and it is also employed extensively in other departments of industry. This fluid has a corrosive action upon the metal of tank cars when exposed to it, and owing to this the inner surfaces of the cars are generally coated with a suitable acidproof compound.

Many of us can recall that chlorine gas was extensively employed by the chemical warfare services of the belligerent countries during the late titanic conflict, and for that reason provision had to be made for the transportation in bulk of large quantities of liquid chlorine. The tank car was adapted to meet this need. It was plain that the tanks for this purpose had to be made of more than common strength and especially sealed so that none of the chlorine could escape. Furthermore, safety valves had to be provided that would not vent until the pressure of the gas generated by the chlorine had reached 200 pounds. What the problem was can better be understood if we recall that liquid chlorine is obtained from gaseous chlorine by means of refrigeration and high compression. Therefore, when the liquid is exposed to the influence of heat it tends to return to the gaseous state and to develop explosive pressures. Owing to these characteristics, tank cars carrying liquid chlorine are required to withstand an internal pressure of 300 pounds to the square inch. To reduce the effect of external heat, the cars are covered with an insulating material several inches thick.

Cars for the transportation of acids are loaded and discharged through openings or connections at the top: most other tank cars are unloaded through one or more outlets on the underside. Compressed air is widely employed for discharging some of these commodities—the air pressure forcing the liquid out and upward into neighboring storage tanks. By this procedure, the risk of handling powerful and harmful acids is reduced to a marked degree.

Substances that are likely to congeal when chilled, such as molasses, asphalt, pitch, lard, linseed oil, cottonseed oil, etc., call for tank cars fitted with internal coils of piping through which steam can be passed to heat and to melt the commodities so that they can readily be pumped out or discharged by gravity by way of bottom outlets or connections. Tank cars intended for the transportation of milk, grape juice, and wine are either enamel or glass lined so as not to injure the palatability of these foodstuffs. This brings us to the story of how the tank car helped to break the grip of a monopoly which was in a fair way to greatly hamper the transcontinental shipment from California of one of its principal products, wine.

A nationally known firm, about 1910, was operating press houses in North Carolina, Virginia, New York State, Ohio, Missouri, and California. The cost of wooden cooperage had advanced materially, and the industry on the Pacific

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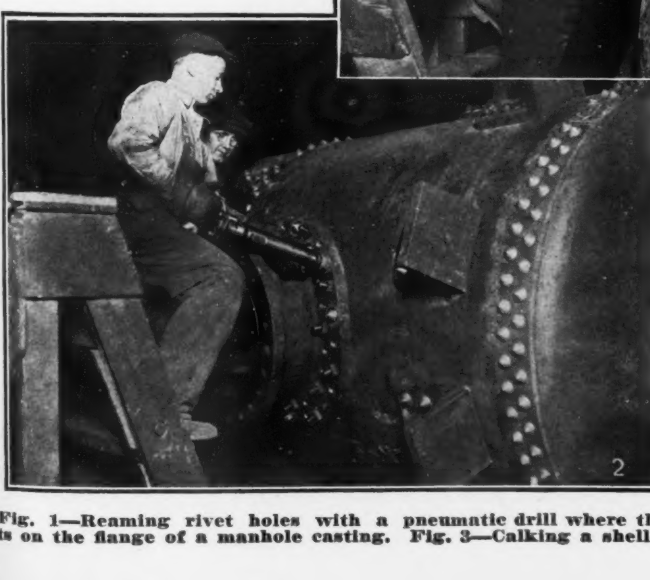

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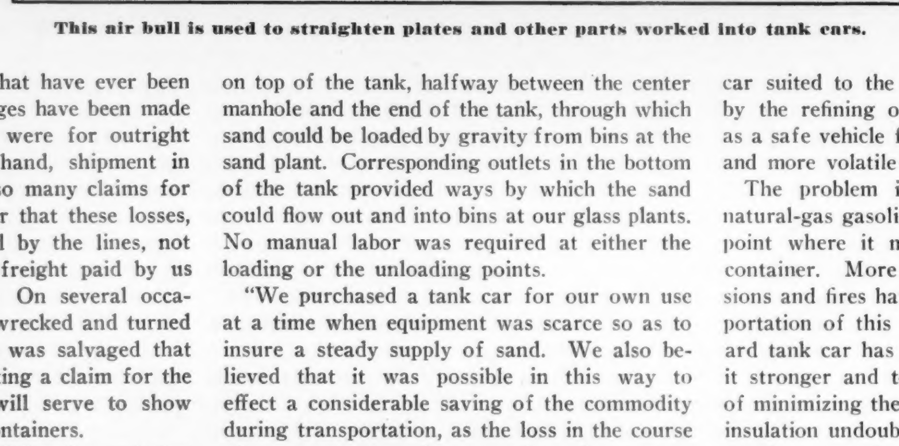
Fig. 1—Reaming rivet holes with a pneumatic drill where the shell and the head join. Fig. 2—An Ingersoll-Rand air hammer driving rivets on the flange of a manhole casting. Fig. 3—Calking a shell-plate seam with pneumatic calking tools.

coast had fallen into the hands of a combination. It was then proposed to substitute enamel-lined tanks and to place two of them, having a total capacity of 1,000 gallons, in each box car adapted to this service. It was not long before the company had a fleet of 30 of these cars at work. Subsequently, the fleet was swelled by the addition of a number of tank cars of the conventional type which were insulated with a non-conducting material and lined with enamel.

This air bull is used to straighten plates and other parts worked into tank cars.

We are indebted to Mr. Paul Garrett for the following particulars regarding the performances of the wine tank cars. "In the shipment of several million gallons of wine, practically the only losses that have ever been sustained or for which charges have been made against railroad companies were for outright wreckage. On the other hand, shipment in barrels was attended with so many claims for loss in the course of a year that these losses, which were uniformly paid by the lines, not infrequently exceeded the freight paid by us in the same twelvemonth. On several occasions, when our cars were wrecked and turned over, so much of the wine was salvaged that it was not worth while making a claim for the difference. One incident will serve to show the ruggedness of these containers.

"A car was wrecked in Colorado, and that vehicle and its tanks rolled at least 50 feet down the slope of a rocky gorge into the bed of a creek, which was then dry. The tanks, still filled, were lifted by a crane out of the creek bed and placed upon a flat car—arriving at St. Louis with substantially no loss of their contents." The foregoing serves in part to explain why the adoption of the tank car is steadily widening.



Air receivers connected with two of the big Imperial compressors which furnish motive air for various purposes in the plant.

As numerous dry materials flow readily, it may be asked why the tank car has not been used for some of these? And the answer is: it has. The traffic manager of the National Lamp Works, Nela Park, Ohio, tells how the tank car has been modified to handle silica sand used in making electric light bulbs. "We had the tank-car company make an additional opening at each end on top of the tank, halfway between the center manhole and the end of the tank, through which sand could be loaded by gravity from bins at the sand plant. Corresponding outlets in the bottom of the tank provided ways by which the sand could flow out and into bins at our glass plants. No manual labor was required at either the loading or the unloading points.

"We purchased a tank car for our own use at a time when equipment was scarce so as to insure a steady supply of sand. We also believed that it was possible in this way to effect a considerable saving of the commodity during transportation, as the loss in the course of a year amounted to anywhere from 25 to $33\frac{1}{3}$ per cent. of the tonnage moved. This wastage occurred in loading, unloading, and while cars were in transit owing to the fact that sand will leak out through the tiniest of holes in a box car. Since adopting the tank car we have experienced none of the losses mentioned."

Hundreds of millions of gallons of casing-head gasoline are now extracted from the gases given off by oil wells and by many natural-gas wells. This gasoline has swelled measurably the total amount of the motive fuel now produced annually by our refineries; but casing-head gasoline is extremely volatile and difficult to transport in its unmixed state unless special precautions are taken. That is to say, the ordinary tank car suited to the carriage of gasoline derived by the refining of petroleum will not answer as a safe vehicle for the shipping of the lighter and more volatile derivative.

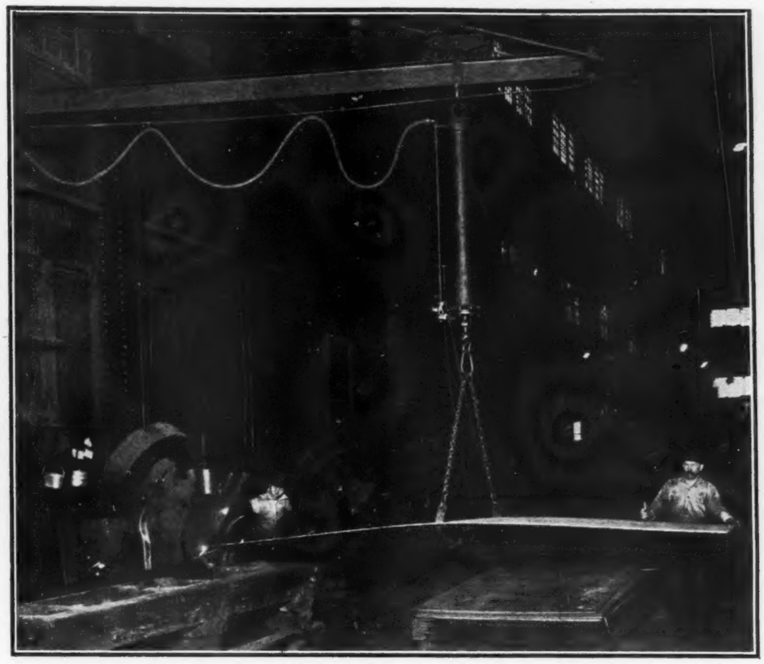
The problem is to keep the pressure of natural-gas gasoline in transit from rising to a point where it might burst the shell of the container. More than once disastrous explosions and fires have occurred during the transportation of this fluid. Therefore, the standard tank car has been modified so as to make it stronger and to insulate it for the purpose of minimizing the effect of external heat. The insulation undoubtedly tends to keep down the development of rupturing pressures; and the United States Bureau of Mines has declared that, because of this action, insulated cars are more desirable for the shipment of casing-head gasoline not only from the standpoint of safety but likewise because of economy. Added security in discharging tank cars loaded with this fuel is assured by employing compressed air to force the liquid up and out of the tank and into a convenient reservoir. This obviates the removal of the dome cover, and makes the whole performance a "closed circuit."

More — much more — could be told about these vehicles, but our space is limited. Now let us take up some of the phases of their construction; and, by way of example, we will follow the procedure in the shops of one of the foremost of the builders

of these conveyances, The Petroleum Iron Works Company, Sharon, Pa. We shall then see that compressed air has much to do in fashioning cars of this kind.

Broadly stated, the construction of the tanks for tank cars follows the practice in vogue in certain big boiler-making plants, because the physical requirements are akin.

The tank for the 10,100-gallon car is 31 feet 6¾ inches long and has a diameter of 7 feet 3½ inches, while the 8,050-gallon tank is 31 feet 8¾ inches in length and has an internal diameter of 6½ feet. The shell of each tank is made up of three longitudinal plates—the plate forming the bottom being heavier than the two upper ones. The heads or ends are also of heavy plating, ½ inch thick, which is dished by a powerful press that incidentally bends the annular flange by which the head is riveted to the shell.



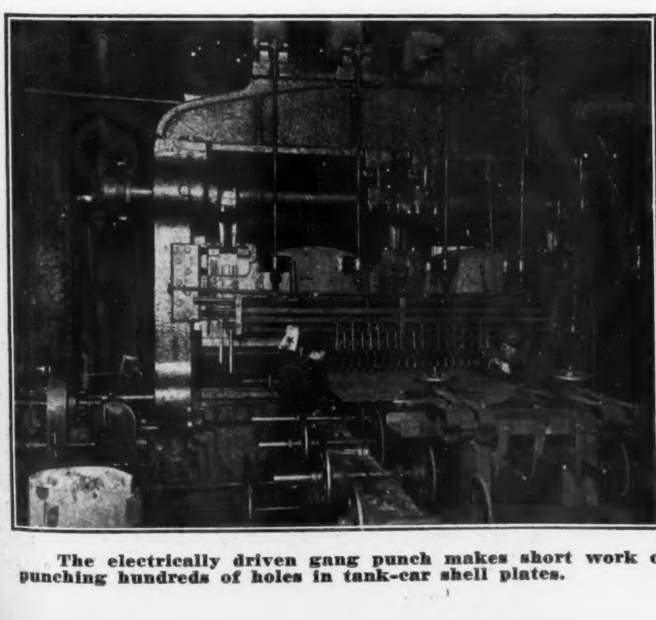
Shell plates are bevel sheared to give them calking edges, and they are held at the desired height by an air hoist while being run through the machine.

The shell plates are punched with their multiple holes by an electrically driven gang punch which makes the rivet holes along the sides and ends of the plates. Numerous holes are punched at a single operation, and the exact spacing is regulated by a spacing table having a perforated longitudinal bar into which pins can be put to halt the successive motions of the plate. The plate travels lengthwise through the machine, but it can be shifted laterally so as to stagger the flanking rows of holes. After a plate is punched it is carried to a jib crane equipped with a pneumatic hoist, and by this hoist the sheet is held at just the right height when being run through shears which bevel the ends and sides to give them calking edges. The plates pass through the shearing and beveling machine at the rate of from eighteen to twenty feet a minute. By the next operation the plates are put through rolls which give them the desired transverse curvature so that when three of them are bolted together they will form a cylinder.

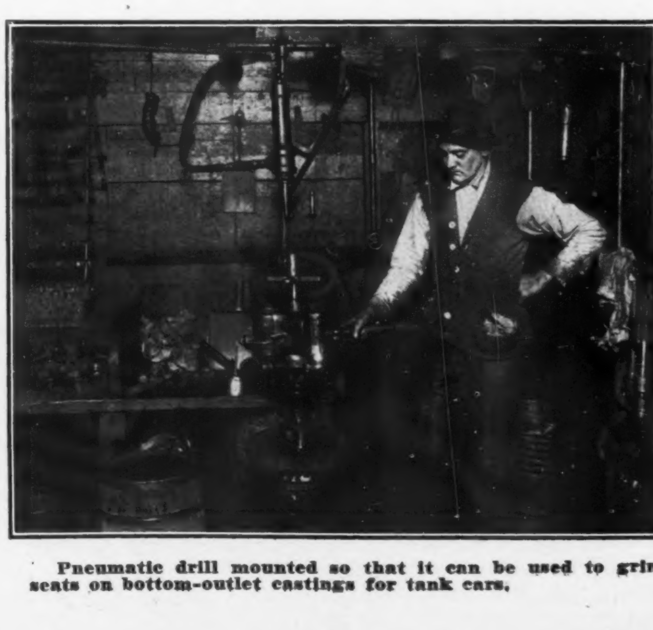
In assembling a tank, the bottom plate is laid first, and then the two associate side and top plates are fitted to it and to each other. The accuracy with which neighboring holes are punched makes it possible to bolt up a tank rapidly and precisely before starting the riveting. A finished tank, that is, one ready to be placed on its trucks and underbody, is held together by no fewer than 1,600 rivets. Inasmuch as the tanks must be watertight to pass the required pressure test, the rivets have to be driven tight so as to insure a very snug bond at every seam. This work is done in two ways: by hydraulic bulls or riveting presses which engage the red-hot rivets at both ends and force them into position, and by the more familiar air-operated rivet hammers. Substantially 900 of the rivets are bull riveted, while the remaining 700 are put in place by hand with pneumatic riveters. The manual driving of the latter rivets is exacting work and necessitates the use not only of powerful hammers but of pneumatic air dollies which hold the rivets firmly in position from inside the tank while the hammers are finishing them off from without. As a matter of fact, this wide-awake shop has devised a number of pneumatic tools or combinations of air-driven tools which make it possible to drive rivets in difficult places and to drive them tight. Among these facilities is what is termed a "windjammer"—a heavy bar of steel carrying an air hammer at one end and a pneumatic bucker-up at the other.

All seams are calked with air-operated calkers; and to insure tightness the seams are calked both inside and out. Excess metal at laps is cut away or rounded with air chisels or chippers. Rivet holes are reamed pneumatically; but the means utilized for reaming the holes for bull rivets and the holes for rivets to be driven with the pneumatic hand riveters are not alike. That is to say, the reaming preparatory to driving bull rivets is done by a machine actuated by an Ingersoll-Rand air motor, while the handy pneumatic drill serves satisfactorily for the reaming of the other holes.

When all the riveting has been finished each tank is tested by filling it with water and then by subjecting it internally to an air pressure of 60 pounds. Air is used for this purpose because it is convenient—being tapped from the compressed air lines which reach everywhere throughout the plant. Any leak will be disclosed either by water or by the audible hiss of escaping air. In the case of tank cars for



The electrically driven gang punch makes short work of punching hundreds of holes in tank-car shell plates.

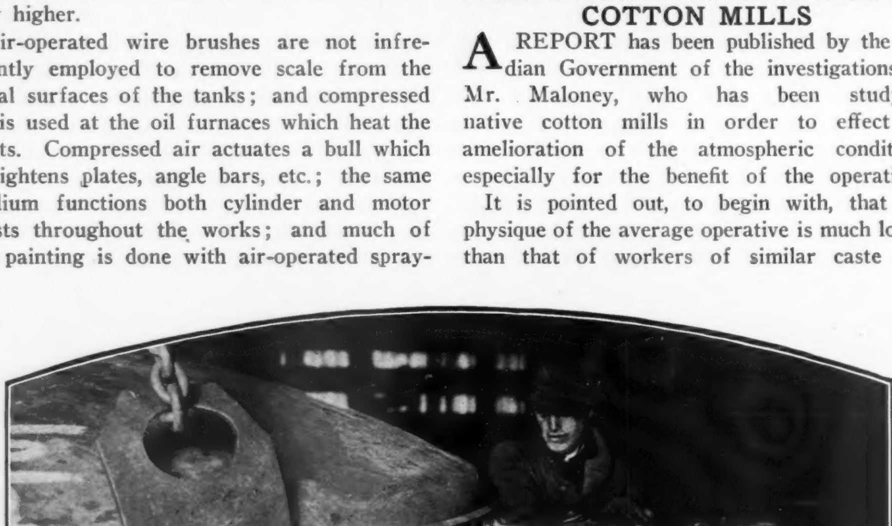


Pneumatic drill mounted so that it can be used to grind seats on bottom-outlet castings for tank cars.

The steadily widening adoption of by-product coke ovens in place of the old beehive ovens has brought about a greater use of tank cars for the carriage of profitable fluid by-products.

certain services the test pressure is considerably higher.

Air-operated wire brushes are not infrequently employed to remove scale from the metal surfaces of the tanks; and compressed air is used at the oil furnaces which heat the rivets. Compressed air actuates a bull which straightens plates, angle bars, etc.; the same medium functions both cylinder and motor hoists throughout the works; and much of the painting is done with air-operated spray-



Hydraulic bull riveter, capable of exerting a pressure of 125 tons, at work riveting a tank-car head.

ers. It should be self-evident that plenty of air is required to meet the diversified demands made by the different departments of the plant; and to do this there has been installed a battery of compressors capable of supplying 4,860 cubic feet of air every minute.

Brazil now ranks fourth among the countries leading in the production of cane sugar. Cuba holds first place, then comes India, and next in line is Java.

HUMIDIFICATION PROBLEM IN COTTON MILLS

A REPORT has been published by the Indian Government of the investigations of Mr. Maloney, who has been studying native cotton mills in order to effect an amelioration of the atmospheric conditions especially for the benefit of the operatives.

It is pointed out, to begin with, that the physique of the average operative is much lower than that of workers of similar caste and wage-earning capacity in other trades. After a few months of continuous service, the workman's weight decreases, and conditions in other ways adversely affect the health rate—the main influence being that of humidity rather than temperature.

More effective ventilation, roof spraying, prohibition of the use of idle steam, and increased velocity of air in the weaving department are among the suggestions offered to promote better atmospheric conditions.

GOOD ROADS SHOW

THE Fifteenth National Convention of the American Road Builders' Association and the Highway Industries Exhibit were held in Chicago, Ill., from January 14 to 18, inclusive—the exhibit occupying the Coliseum during that period. The Good Roads Show attracted engineers, contractors, and public officials from all parts of the country. Much interest was also evinced by the average citizen who, after all, is most concerned in the improvement and the proper maintenance of the nation's vehicular arteries of communication.

The show suffered from only one handicap—space available was not equal to the demand; and this shortage revealed the record-breaking character of this very significant annual event. In order to derive the greatest benefit from a show of this character, plenty of elbowroom is desirable so that both large and small machinery can be displayed to advantage. This means that all equipment which can be operated should be run well-nigh continuously so that demonstrators can make the most of the occasion and prospective purchasers try out the tools and machines as well. In this way, the purchaser obtains first-hand information and is thus enabled to make an accurate and a shrewd comparison of competitive facilities offered by rival manufacturers.

It is authoritatively declared that no fewer than 15,000 people attended the show; and those people are going to carry home to every section of the country a stirring story of what is being done by engineering concerns to provide roadbuilders with equipment that will give them the means with which to construct and to keep in repair the nation's highways with the least delay and at a moderate cost. One of the outstanding features of the show was the mobility of the machinery displayed—there were portable power shovels, excavators, cranes, concrete mixers, air compressors, etc. A few years back outfits of this sort were not even thought of.

At first blush, it seemed as if a number of the exhibitors were bent upon outdoing one another in the making of noise. This was due to the fact that many had working exhibits; and among those that won distinction in this respect were shovel manufacturers, concrete-mixer manufacturers, and the Ingersoll-Rand Company. The latter's exhibit was of an intensely practical nature and was designed to tell its story through action. A huge block of Tennessee marble, donated by the Gray Eagle Marble Company of Knoxville, was gradually honeycombed with holes by the frequent attack of the famous I-R "Jackhamer" rock drill. Further, the Ingersoll-Rand pneumatic spade and the backfill rammer never failed to interest a crowd of onlookers whenever they were put to work.

Among the things shown by the Ingersoll-Rand Company were its well-known line of portable air compressors, as well as pneumatic paving breakers, air hoists, drill sharpeners, etc. In short, the company's exhibit included a variety of pneumatic apparatus largely intended to meet the special problems of the roadbuilder. They are the result of much study and the fruit of ripe practical experience.

Safe Compressed Air Practice

By FRANK RICHARDS

THE PURPOSE is to consider here what are the conditions most essential to be followed in safe and in economical compressed air practice, with a special lookout all the while for the avoidance of explosions anywhere in the system. By "explosions" is meant those of a violent and destructive character which result from the formation and then the ignition of explosive mixtures composed of compressed air and such combustible material as is believed to be set free from the lubricating oils employed. No consideration is here given to explosions due to static pressure in excess of the strength of the enclosure because, with air, they are incomparably less violent and have been sufficiently studied and safeguarded against in practice.

As a starting point, let us take for consideration a complete compressed air installation in full operation, and then deal with each outstanding detail as it is reached. First, there is the air to be compressed. The talk about getting dry air to begin with is more or less absurd, as will be made clear later; but clean air is of prime importance, and it is quite possible to get this although comparatively few people are aware of this through actual acquaintance.

All air carries dust—sometimes much of it, visible and invisible. When air is compressed to eight atmospheres, for instance, each cubic foot of it will contain eight times as much dust as free air, and this dust will be commingled with eight times the normal quantity of oxygen, so that here is a presumptive explosive mixture to begin with. Who can say that many mysterious compressed air explosions have not been just dust explosions, such as frequently occur in flour mills and elsewhere?

Even in cases where oil vapor has been the principal constituent of the explosive mixture, minute particles of combustible solids have, in all probability, also contributed their quota and thus aggravated the matter. I do not know that anyone has ever suggested this before, but it is certainly deserving of serious consideration. The removal of dust from air is much to be desired owing to the way it affects the life and the running of pneumatic tools and other apparatus employing it. Those who have the supervision of such tools well know the trouble caused by abrasions and obstructions due to dust accumulations.

The abstracting of dust from the entering free air is a very simple affair, and it is one of the operations in connection with compressed air that costs but little. This precaution should be exercised, although there are many who do not realize how imperative it is. The first providing of the simple device employed is all that is required. To get rid of practically all the dust in the air we have only to strain it, and for that we must furnish and put in place a strainer. There are several types of air filters for this purpose on the market. The ordinary cloth strainer stretched over a wire-mesh frame may also be used successfully if the fabric be cleaned or renewed frequently. The intake air should be led to the filter and to the compressor cylinder through a pipe of generous capacity from outside the compressor building or down through the roof, above which the air is coolest.

Now, as to the compression of the air—assuming that the air is to be compressed as it so commonly is to 100 pounds gage pressure. This pressure, of course, will be attained by 2-stage compression, going to about 27 pounds gage in the first cylinder. With the intake air at 60°F., the discharge temperature will be about 230°F., and this is the temperature at which the air will enter the intercooler. In passing through the intercooler, the temperature of the air should be reduced to 100° or less, with a corresponding reduction of volume. This reduction of temperature and volume is the chief function of the intercooler and the reason for employing 2-stage compression, which results in a saving of about 15 per cent. in power. The lowering of temperature and the lessening of volume incidentally reduce the moisture capacity of the air, usually carrying it below the saturation point. A small portion of water—that which is in excess of the moisture-carrying capacity of the air—will be liberated. It will not, however, be "precipitated," as is too generally assumed, but will still remain distributed throughout the air in the form of minute globules of water.

Unless the intercooler also embodies a separator, or has a separator supplementary to it, through which the cooled air must pass before entering the high-pressure cylinder, the air will carry with it into that cylinder all the moisture it originally contained, or the air, which in any case would be saturated with water vapor or steam, will be supersaturated by the condensed moisture which has not been separated. The separator is necessary not only to take care of this excess moisture, but it will also serve the important purpose of catching whatever oil may have been carried along to this point. An efficient separator, which it is easily possible to provide, should always be a part or a supplementary companion of the intercooler.

The air, necessarily at or near the saturation point, now enters the high-pressure cylinder at a pressure approximating 27 pounds, gage, and at a temperature of about 100°F.—that is, if the intercooler be effective in itself and provided with cooling water at a sufficiently low temperature. The temperature of the air after its final compression to 100 pounds will be about 240°F.; and this being the case the temperatures in either of the cylinders will not come anywhere near the danger point. The figures used throughout this article are only roughly—some may say rashly—approximate, but they should not prove misleading.

The aftercooler and the final separator are the most important and responsible features of any safe, economical, and satisfactory air-compressing installation. The air which enters the high-pressure cylinder saturated with moisture is discharged from that cylinder in a comparatively "dry" condition. This is because the capacity of the air for carrying moisture has been much increased by the rise in temperature even though its volume has been considerably reduced by compression. It is the function of the aftercooler to bring the temperature of the air to as low a point as practicable while at its highest pressure. These two conditions coöperate to reduce the water-carrying capacity to a minimum, and it is then the business of the separator to catch and to hold all the moisture that is set free. A separator which works effectively with steam will perform with equal success when handling air. It should not only entrap and secure all the liberated moisture in the air but, similarly, arrest any oil which might be carried through. With care on the part of the engineer there should be but little of the latter to be caught by the separator. A filter aftercooler and a separator, acting together, will reduce the possibility of excess oil collecting in the receiver and the pipe lines, and to this extent they will lessen the likelihood of conditions arising favorable to an explosion.

As a further precaution, it is advisable to periodically clean the compressor system. The compressor can be cleaned by using a solution of soft soap and water—the suds being fed through the lubricator for a few hours and then followed by oil to prevent rusting. The aftercooler and the receiver can be cleaned by using a solution of lye and water that can be introduced into the discharge pipe by a lubricator or its equivalent—the latter being made of ordinary pipe fittings.

When the air is cooled in the manner described and freed of dust, moisture, and oil, it will then be in the best possible state for any employment, near or distant, to which it may be put.

I set out to sketch the general procedure involved in compressing air to ordinary working pressures, keeping in mind the possibility of destructive explosions and looking out for the causes leading to them—the object being to make clear how to avoid them. I have succedeed in showing only how not to do so. There is invariably one thing preceding and leading up to air compressor explosions, and that is the use of too much lubricating oil in the air cylinders. The thing to do is to use as little oil as possible. In my book, *Compressed Air Practice,* I called attention to the wonderful record—which, after all, should not have been so wonderful—of oil economy in the air-compressing installations of the Panama Canal job; and then on the same page I gave an authenticated account of the finding in an air receiver of 110 gallons of lubricating oil. That showed that some operators employed many times more oil than necessary for the proper functioning of the compressors.

The aftercooler has various other advantages by reason of its moisture-removing service, such as: the prevention of the freezing of tools, hose, and pipe lines, and the cutting down of wear in tools that follows when water washes out the lubrication.

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EDITORIALS

HARNESSING THE TIDES

THE TIDES have been harnessed and put to work in a modest way for a long while, but in the last few years the engineer has suggested means by which this might be done on a magnificent scale. None of these schemes has been more ambitious than that recently made public which embraces the utilization of the notably wide tidal range of the ebb and flow of the waters of the Bay of Fundy. As may be recalled, the tide rises 70 feet in some parts of that body of water, and the author of the project, DEXTER P. COOPER—a brother of HUGH L. COOPER, the well-known hydraulic engineer—proposes to impound a section of the area so as to develop a great block of electrical energy.

The plan, so we are told, would involve the building of dams five miles long across Passamaquoddy Bay—really an estuary of the Bay of Fundy—on the international boundary, and the erecting of a power plant between an upper and a lower reservoir capable of developing something like 500,000 H.P. According to the *New York Times*: "A number of gates would be installed in the bay to release the great flood tide into the upper pool and to empty the lower one at low tide. It is estimated that a stream of water about the extent of Niagara would be continually running through the gates." Suitable locks in the dams would make it possible for shipping to enter and to leave the impounded area.

While the project would unquestionably involve an outlay of a great many millions of dollars and take years to carry out, still the essential features are sound in principle, so it is said. If built, the electricity generated would be a boon to industries in Maine and in eastern Canada and be the means of greatly stimulating the establishment of additional manufacturing plants in those parts of the two countries.

Monumental as the plan seems, still much of it rests upon what has already been done in other great engineering undertakings which were once believed impossible of accomplishment. Their successful execution has brought about the development of apparatus and has furnished data which give the engineer assurance and warrant for essaying even greater things. As the tides have been employed for centuries in operating tidal mills, etc., it is only reasonable to suppose that the technicist will find ways and means to make use of this power on a scale commensurate with the march of human progress.

SHANDAKEN TUNNEL IN SERVICE

THE COMPLETION of the Shandaken Tunnel is an engineering accomplishment of the first magnitude; and by this rock-hewn conduit it will be possible to add 600,000,000 gallons of water daily to New York City's cup.

The fact that the Shandaken Tunnel is 18.2 miles long and, therefore, 30,698 feet longer than its nearest rival, the famous Simplon Tunnel, does not suffice to bring out the engineering significance of this great artificial artery which now links Schoharie Creek with Esopus Creek on opposite sides of a towering mountain. The execution of the work has involved the surmounting of numerous natural obstacles, and has necessitated the sinking of several deep shafts in normally rather inaccessible locations. But once sunk, these shafts have enabled the contractors to drive headings along the tunnel line in two directions from all but one of the seven shafts. Undoubtedly this procedure has aided materially in bringing about the completion of the tunnel months earlier than the date set in the original contract signed in November of 1917.

To appreciate the size of the task, it should be recalled that the work has required the excavating of 601,625 cubic yards of rock in sinking the seven shafts and in driving a tunnel passage large enough to give a finished aqueduct 10¼ feet in width and 11½ feet in height. At times, the workers were able to advance an aggregate of more than a mile from twelve headings in the course of a month; and this progress could not have been made but for the employment of pneumatic rock drills and air-operated mucking machines to deal with the blasted rock and to load it onto mucking trains. All told, fully 12,000 holes, each 16 feet deep, were drilled in the rock at the tunnel headings, and into these a tidy matter of 2,500,000 pounds of dynamite were placed for the purpose of shattering the backbone of Shandaken Mountain.

If the course of the tunnel had pierced only solid rock of sturdy texture, the problem of the excavators would have been a far simpler and less hazardous one. As it was, the line of progress carried the men through some rock that was filled with veins of water, and part of the advance was through shale of a decidedly unstable nature. This shale, in places, rumbled and groaned overhead as it readjusted itself and released the pent-up stresses produced by many thousands of years of compression; and on occasions this fairly rotten rock spawled when exposed to the air and dropped out in large pieces. As we are told, scalers, men equipped with long steel rods, sounded the ceiling continually to detect weak spots and to guard against death-dealing collapse. It is little short of marvelous that not a single life was lost by reason of stone dropping from the roof of the tunnel.

The tunnel is lined with concrete, not less than three inches thick, and the arch portion has in the main been placed by means of concrete guns operated by compressed air. In building the tunnel and in reinforcing the vertical shafts a matter of 295,000 barrels of cement have been utilized. To date, this unit in New York City's Catskill Water Supply System has called for an expenditure of $12,300,000. Full credit for much of the splendid work done must be given the Shandaken Tunnel Corporation and the Engineering Bureau of the New York Board of Water Supply.

DESULPHURIZATION OF COKE

TODAY, coke is made only from low-sulphur coals; and it has long been recognized that it would be a matter of much economic importance if high-sulphur coals could be employed in the production of coke. Such an achievement would make available coals from many fields that cannot now be utilized for the manufacture of metallurgical coke—one of the indispensable raw materials required in the steel industry.

The Carnegie Institute of Technology and the United States Bureau of Mines have collaborated in experimental work which has disclosed that coke can be effectually desulphurized by steam to a degree not possible by any other recognized process. Sulphur in metallurgical coke gives rise to many problems and difficulties in furnace operations; and coke containing more than 1¼ per cent. of sulphur is likely to lead to an inferior grade of iron that is difficult if not impossible to work. Therefore, both the manufacturer and the consumer of coke have every reason to be interested in any method which renders it feasible either to get rid of the sulphur content entirely or to reduce it to a permissible degree.

Many processes have been tried in the past for the removal of sulphur from coke, including the use of steam; but most of these efforts have been unsuccessful. In their recent work, the investigators have found that anywhere from 10 to 15 per cent. of the total sulphur in the coke can be removed by steaming it at a temperature of 1,382°F. The sulphurization can be increased to from 20 to 25 per cent. by subjecting the coke alternately to vacuum and pressure treatments. We are authoritatively in-

formed that there is warrant for the belief that steaming is much more beneficial than the actual sulphur reduction would seem to indicate. That is to say, the sulphur removed by the process is taken almost entirely from the surface of the coke; and the assumption is that it is surface sulphur which is most readily absorbed by the iron in the blast furnace.

The average annual coke production in the United States during the last ten years has been 45,404,000 tons; and about 60 per cent. of this has been used in metallurgical industries while the remainder has been consumed in the making of so-called domestic gas. The coal utilized for this purpose has represented approximately 15 per cent. of the bituminous coal mined annually in this country.

It is recognized, of course, that desulphurization by steaming will not be industrially practicable as long as there is an ample supply of low-sulphur coals; but inevitably this situation will change. When that day comes, the by-product coking industry will furnish the heat—now going to waste—for the generation of the needful steam. Once again the men in the laboratory have anticipated the future needs of the nation and have thus provided against a contingency which might be a cause for grave concern.

WORK has been started by the Southern Railway at its Finley yards, Birmingham, Ala., on the erection of a mammoth locomotive plant which will call for an outlay of some millions of dollars. The magnitude of the project can be gathered from the fact that the shops will be served by more than ten miles of track; and, when running, the plant will give employment to fully 1,200 mechanics.

The foundations of the buildings and the foundations for the various heavy machines will be constructed at the same time; and as the walls go up machinery will be put in place so that the equipment will be ready to operate as soon as the roofs are completed. The plan is to have the shops finished by the first of next October. The buildings and every phase of their outfitting are in keeping with thoroughly up-to-date practice; and this undertaking gives convincing evidence of the enterprise and the healthy state of the Southern Railway System. Dwight P. Robinson & Company, Inc., are the engineers and general contractors handling the job.

THE United Engineering Society, having a membership of 54,224, has recently elected Mr. William L. Saunders to succeed Mr. J. Vipond Davies as president of the organization. Mr. Saunders is chairman of the board of the Ingersoll-Rand Company of New York, chairman of the Naval Consulting Board, deputy chairman of the Federal Reserve Bank of New York, and a past president of the American Institute of Mining & Metallurgical Engineers, of the New York Chamber of Commerce, and of the American Manufacturers Export Association. He is also a member of the American Iron & Steel Institute, of the American Society of Civil Engineers, and of the American Society of Mechanical Engineers.

BOOK REVIEWS

KEY TO NATIONAL PROSPERITY, by Jules Nahoum, Secretary, American-European Finance Corporation. A book of 381 pages, published by E. P. Dutton & Co., New York. Price, $6.00.

THE CONDUCT of foreign trade has been viewed by many people as no more complicated than any ordinary business undertaking, and this lack of the grasp of the problem probably explains why the efforts of such people have all too often brought them failure. The author states explicitly in his preface that "The business of foreign trade is a profession. It cannot be taught by theories. The successful importer or exporter is a practical man who has gone through practical apprenticeship in all the phases of that business and who is familiar with all the intricacies and problems connected with it."

National prosperity, as he emphasizes, is largely dependent on commercial relations with other countries. The purpose of Mr. Nahoum's book is to give an outline of the more important facts to be considered in this field of endeavor; and the work deals with the larger economic aspects of the subject rather than the day-to-day technical routine of import and export. It is intended to serve as a guide rather than to lay down hard and fast rules for observance. The author has covered his topic in an entertaining and an instructive manner, and the volume should prove of value to any one engaged in foreign trade or contemplating going into it.

ECONOMICS OF MOTOR TRANSPORTATION, by Geo. W. Grupp, consulting statistical economist. A work of 414 pages, with numerous graphs, published by D. Appleton & Co., New York. Price, $4.00.

THE DEMAND for a book of this sort comes principally from four directions—students in schools and colleges, motor-vehicle manufacturers, owners of commercial vehicles, and prospective owners. Interest is due principally to the fact that those concerned realize that in a commercial, manufacturing, or engineering career they will be directly or indirectly affected by road transportation. To meet the four-fold demand mentioned, the author has tried to make a book that would cover the entire field in a reasonably detailed manner; and special effort has been concentrated on the exposition of the principles involved and the description of the methods of applying them. This truly excellent volume contains a wealth of worth-while data, and it will undoubtedly prove a help to any one interested in this subject.

THE BUSINESS LETTER, ITS PRINCIPLES AND PROBLEMS, by Carl A. Naether, Associate in Journalism, University of Michigan. A volume of 516 pages, published by D. Appleton & Co., New York. Price, $4.00.

THE LETTER in business has gained in importance in latter years because business enterprises are awakening to the effects for good or bad which may be made by routine correspondence. There is an insistent demand for clearness, courtesy, and brevity in presenting every-day business facts; and it is realized that business can be secured by letter only by making that letter appeal.

Mr. Naether has produced a book which has much to commend it. It offers a thorough training in the writing of effective business letters of all sorts. It presents in concise form the principles of modern business letter writing and drives the points home by giving typical examples in each case. The author, in assembling data for his book, has been in touch with business firms of all descriptions, and the problems discussed have been suggested by this material gathered from the files of business men.

JAPAN—BEFORE AND AFTER THE EARTHQUAKE. ECONOMIC PROBLEMS OF WESTERN EUROPE. These are two pamphlets published by the Commission on Commerce and Marine of the American Bankers Association, and each of them contains a wealth of information. Both topics concern a great many people, and these brochures should reach a wide circle of readers.

CONQUERING THE EARTH. This is the title of a really beautiful brochure published by the Hercules Powder Company of Wilmington, Del.; and the booklet shows in pictures and describes in an entertaining fashion some of the outstanding periods or stages in mining and quarrying from the days of Solomon down to 1750. As might be expected, the author has introduced data which brings out forcefully what modern explosives have made possible in breaking through Nature's rocky barriers.

The same company has also prepared for distribution a pamphlet entitled, FUMES ENCOUNTERED IN MINING OPERATIONS, AND IN the HANDLING OF EXPLOSIVES. Either or both of these publications can be had gratis upon application to the Advertising Department.

THE Bucyrus Company of South Milwaukee, Wis., has recently issued three new bulletins which should be of interest to contractors and others engaged in heavy excavating work. Bulletin B-201 describes a new 20-B Diesel shovel; Bulletin F-302 deals with the company's 30-B Diesel or gasoline shovel, dragline, and crane; and Bulletin C-304 covers the 30-B steam shovel, dragline, and crane, which is also a new product.

SOLVING YOUR COOLING WATER PROBLEM, by B. H. Miller, M. E. It is not necessary for the reviewer of this informative pamphlet of 12 pages to emphasize how important the solution of the cooling-water problem is to the average operator of internal combustion engines and compressors today. Any effective solution of the difficulty will be welcomed by thousands of plant owners and operating engineers. To those to whom this subject appeals, we suggest that they write for a copy of this pamphlet to the Permutit Company, 440 Fourth Avenue, New York City.

NEW BRITISH AIR-MAIL SERVICE

AIRPLANE service in England is not only becoming more widespread but it is settling down into regular lines of employment, especially in the carriage of mail. An airplane service from Plymouth to Manchester and Belfast is to be started by the British Air Ministry, in coöperation with the DeHaviland Aircraft Company, for the purpose of ascertaining what time can be saved in the distribution of American and other overseas mails destined for northern England and northern Ireland.

It is arranged, so it is reported by Consul R. C. Busser, that upon notice by wireless from incoming American mail steamers approaching Plymouth motor trucks will be placed in readiness to transport mail from the steamers to the aerodrome, whence it will be dispatched by 'plane to London, Manchester, and Belfast.

The return journey from Belfast will be made via Manchester and Birmingham, with the intention of linking up with the outgoing steamers at Southampton. Airplanes will proceed no further than Birmingham for the present, as Southampton has no aerodrome suitable for the purpose. Although it is primarily to be an air-mail service, it is reported that arrangements will also be made to carry passengers.

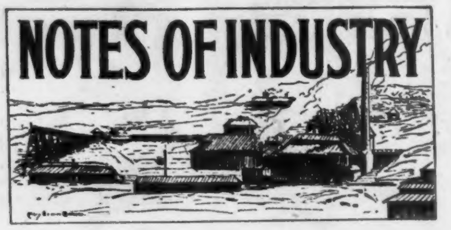
HYDROSTATIC TESTS OF PRESSURE TANKS

THE universally followed practice of testing the strength of steam boilers, receivers, etc., by water pressure seems as safe and unobjectionable as any that could be devised, and yet there are things to look out for when employing it. We have a reliable account—without reference data—of the testing in England of a lap-welded, steel air container which blew out the head. The flying head not only killed a man but it went through a wooden partition several yards away, which suggests the force behind it.

The cylindrical vessel under test was 18 inches in diameter, and it was designed to safely withstand a pressure of 1,000 pounds. The testing pressure reached 1,900 pounds before the accident occurred. It is suggested, and it is presumably correct, that in filling the vessel with water care was not taken to see that it was entirely filled so that all the air had been expelled. A comparatively small volume of air, compressed to more than 100 atmospheres, would be enough to account for the fatal occurrence.

The retail value of passenger cars sold in the United States in 1923 is estimated by B. E. Hutchinson, vice-president and treasurer of the Maxwell Motors Corporation, at approximately $3,375,000,000, or about $144 per family.

Speed of travel appeals to the Chinese, so it would seem, for the modern urge to "step on the gas" has finally extended to the Orient.



In a small railroad shop, not long ago, the engine which drove the machine tools gave out and everything was at a standstill. The air compressor, however, was still alive, so the foreman connected a pneumatic drill to the screw-cutting spindle of a lathe, and thus made it possible to turn up one or two parts that were needed to get the engine going again.

After a complete course of training by instructors of the Bureau of Mines, nearly 30,000 miners in the United States have been granted certificates for proficiency in the use of self-contained, mine-rescue, oxygen breathing apparatus.

Gold production in South Africa in 1923 reached the large total of 9,133,060 ounces, an increase of 2,112,950 ounces over the preceding year. This high mark has been exceeded only once in the history of the mines, in 1916, when the output amounted to 9,296,618 ounces.

The National Administrative Council of Uruguay has about completed its studies of a project for utilizing the waters of the Rio Negro for generating electric power for the City of Montevideo and surrounding towns. Construction work on the dam, which will extend the navigation of the Rio Negro for a distance of approximately 100 miles, is to begin at an early date. The total cost of the undertaking is estimated at $15,000,000 Uruguayan pesos.

One out of every 33 freight cars carried by the railroads of the United States contains cement or supplies destined for cement mills.

The State of Illinois built 1,000 miles of concrete highways in 1923.

The United States Lighthouse Service has in commission more automatic apparatus to aid navigation than any other country in the world. These mechanical devices do the work that would otherwise have to be performed by about 765 light keepers and, in addition, operate 668 lighted buoys—invaluable guides to mariners—which could not be maintained by human attendance.

By the construction of a new tunnel under the Thames River from Tilbury to Gravesend, England, three objects are to be attained. First, the development of the industrial resources of Kent and, incidentally, the eastern half of the south of England; second, the bringing of the north of England into direct relationship with the channel ports; and, third, the relief of the congested condition of London traffic.

The United States burns as many incandescent lamps as all the other countries of the world combined. It is estimated that we use 350,000,000 bulbs annually and that the rate of consumption increases 10 per cent. every twelvemonth. The yearly production of lamps to maintain the supply amounts to approximately 200,000,000. The average candle power per lamp has grown from 16, in 1905, to over 60 at the present time, while the average number of watts consumed has remained at about 55, that is, practically stationary. All this goes to show that we do not save much, but that we do use more light and get more light per unit of current.

The abundance of water power in Norway gives that country a great advantage in supplying hydro-electric service, especially for domestic uses. With about one fortieth of the population, Norway stands second to the United States in the consumption of electricity for cooking and heating. The happy householder there pays by the year instead of on a current-consumption basis.

One state, at least, is making a good showing in forest conservation. According to recent figures of the Department of Agriculture, the timber resources of Montana are increasing at the rate of 200,000,000 feet a year. The annual growth in that state is estimated at 800,000,000 feet, as compared with the reported cutting of 600,000,000 feet for all purposes. The present stand of timber is put at 59,000,000,000 feet.

By far the largest motor ship in the world, and also the most powerful yet designed, is under contract at the Harland & Wolff yards, Belfast. It is to be of more than 20,000 gross tonnage, and is being built for the South African service. The new vessel is to have two sets of double-acting Diesel engines, developing not less than 20,000 indicated horse-power.

An oil company in California—the Pan American—is to build a 10-inch, 140-mile pipe line from the naval reserve in Kern County to its refinery at Los Angeles. The pipe, which is to be completed during the present year, will be welded throughout, and unusual engineering work is involved in crossing the mountains.

According to the National Committee for the Prevention of Blindness, industrial accidents are responsible for an injury to a human eye every 2½ minutes day and night, and every day in the year. Approximately 15 per cent. of the total blind population of the country represents those blinded by accident in the industries.

During a recent riot at Savannah, Ga., when a mob of over 2,000 stormed the county jail in an attempt to get a young negro, the riot call was sounded at fire headquarters. Two motor pumps with sixteen men responded, and the mob was dispersed by a fierce and sudden discharge from four high-pressure streams.

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